Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

JOHN F. KELLY, EDITOR

CONTENTS

Volume XI. FEBRUARY, 1934 No. II

Heat Transfer to the Open Hearth Bath—by William C. Buell, Jr., Engineer, Cleveland, Ohio 57

Discussion—Heat Transfer to the Open Hearth Bath—Discussion presented by W. N. Flanagan, W. C. Buell, Jr., L. Larson, J. L. Miller, H. McClelland, H. V. Flagg, G. A. Merkt, J. E. Dunn, M. J. Conway and Feodore F. Foss 63

Pack and Pair Heating Furnaces in Connection with Sheet and Tin Mills—by R. J. Wean, President, The Wean Engineering Co., Inc., Warren, Ohio 67

Discussion—Pack and Pair Heating Furnaces in Connection with Sheet and Tin Mills—Discussion presented by F. L. Estep, F. E. Leahy, C. H. Verwohlt, R. J. Wean, H. V. Flagg, F. Oppenheimer, G. J. Hagan, T. B. Bechtel, W. E. Blythe and N. B. Ornitz 72

A. I. & S. E. E. Pittsburgh District Section Meeting 75

Recent Developments in Design and Operation of Industrial Furnaces—by G. A. Merkt, Manager, Combustion Control Dept., Morgan Construction Company, Worcester, Mass. 76

Discussion—Recent Developments in Design and Operation of Industrial Furnaces—Discussion presented by C. L. Joly, M. J. Conway, Feodore F. Foss and G. A. Merkt 81

Heating Slabs for Hot Strip Mills—by W. R. Culbertson, Manager, Furnace Division, Rust Engineering Company, Pittsburgh, Pa. 85

Discussion—Heating Slabs for Hot Strip Mills—Discussion presented by J. L. Miller, F. E. Leahy, W. R. Culbertson, H. V. Flagg, H. Dobrin, M. J. Conway and G. T. Hollett 87

New Inland Tin Plate Plant Now in Operation 88

A. I. & S. E. E. Philadelphia and Chicago District Section Meetings 89

Items of Interest 90

A. I. & S. E. E. Iron and Steel Exposition Floor Plan 92

A. I. & S. E. E. Spring Engineering Conference II

Editorial III

Index to Advertisers IV

Published Monthly by

Association of Iron and Steel Electrical Engineers

BOARD OF DIRECTORS—1933-1934

President, W. E. Miller, Mechanical & Electrical Supt., Bethlehem Steel Co., Johnstown, Pa.

1st Vice Pres., W. H. Burr, Mech. and Elec. Supt., Lukens Steel Co., Coatesville, Pa.

2nd Vice Pres., J. A. Clauss, Chief Engineer, Great Lakes Steel Corp., Ecorse, Mich.

Director at Large, A. L. Foell, Chief Engineer, Arthur G. McKee Co., Cleveland, Ohio.

Honorary Director, E. Friedlander, Pittsburgh, Pa.

Honorary Director, J. Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio.

Past Pres., J. D. Donovan, Mech. and Elec. Supt., Republic Steel Corp., Massillon, Ohio

Past Pres., J. J. Booth, Elec. Supt., National Tube Co., Gary, Ind.

Treasurer, G. R. Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.

Secretary, A. D. Adams, Asst. Supt., Spang Chalfant Company, Inc., Ambridge, Pa.

Director, W. S. Hall, Supt. Engr. and Const., Illinois Steel Co., S. Chicago, Ill.

Director, F. E. Leahy, Fuel Engr., Youngstown Sheet & Tube Co., Youngstown, Ohio

Director, J. W. Bates, Elec. Engr., Power Div., American Sheet & Tin Plate Co., Pittsburgh, Pa.

Director, C. C. Pecu, Lubrication Engr., Bethlehem Steel Co., Lackawanna, N. Y.

Director, J. A. Oartel, Safety Director, Carnegie Steel Co., Pittsburgh, Pa.

Director, W. A. Perry, Supt. Elec. and Power Depts., Inland Steel Co., East Chicago, Ind.

Director, W. J. Donahue, Chief Elec., Southern District, Republic Steel Corp., Birmingham, Ala.

Director, C. M. Thompson, Jr., Prod. Engr., Henry Disston & Sons, Inc., Tacony, Philadelphia, Pa.

Director, C. A. Thayer, Chief Engr., Republic Steel Corp., Youngstown, Ohio.

Managing Director, John F. Kelly, Empire Building, Pittsburgh, Pa.

Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
Subscription Price $5.00 per Year. Single Copy $1.00.

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

ANNOUNCE THE

Spring Engineering Conference

AUSPICES

Combustion Engineering Division

OHIO HOTEL

YOUNGSTOWN, OHIO

WEDNESDAY EVENING, APRIL 11, 1934

7:30 P. M.

THURSDAY, APRIL 12, 1934

9:30 A. M.

THE FOLLOWING TIMELY SUBJECTS WILL BE PRESENTED AND DISCUSSED BY NATIONAL AUTHORITIES

Chairman, F. E. LEAHY,
Fuel Engineer, Youngstown Sheet & Tube Co.,
Youngstown, Ohio

Secretary, J. L. MILLER,
Asst. Chief Engineer, Carnegie Steel Co.,
Youngstown, Ohio

SUBJECTS

PICKLING

BILLETS, SHEET, TIN AND STRIP

ELECTRO CLEANING OF STEELS

ABRASIVE CLEANING OF STEELS

HOT GALVANIZING

IN CONNECTION WITH SHEETS

SUPER-REFRACTORIES

HEAT RESISTING METALS

ELECTRICALLY HEATED FURNACES

ANNEALING AND NORMALIZING

BOX ANNEALING FURNACES

GAS FIRED THROUGH HEAT RESISTANCE TUBES

Make Arrangements NOW to Attend
Come and bring your associates

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

E D I T O R I A L

Change—Progress

▲

The history of the Steel Industry has been epochal in its nature. Chainlike in effect, these epochs have been stamped with the same characteristics. They were marked by men of vision and imagination who were always seeking to change so as to progress. Our Modern Blast Furnaces, Open Hearths and Rolling Mills are the results of men, who refused to be smug with the methods of doing things the way they were always done, but were determined that better ways could be found.

Men, of this nature, were responsible for the advent of steam which was one of the great marks in the progress of the Steel industry. Its application to rolling mills increased production to amazing high figures; it mitigated drudgery and was one of the outstanding impulses in the development of our present modern machine technique. While the application of steam as a means of motivation in our industry cannot be ignored and its contribution to the progress of the industry in any way slighted, the introduction of the electric motor marks the outstanding epoch in the history of the industry.

This epoch of the electric motor spans the life of the A. I. & S. E. E.—the Engineering Society of the Steel Industry whose 2,000 members are still dissatisfied with the ways of making steel. They are determined to make steel better and thus help to make another epoch in the history of steel manufacture.

INDEX TO ADVERTISERS

A

THE ALLIANCE MACHINE CO. 118
ALLIS-CHALMERS MFG. COMPANY 119
ALUMINUM COMPANY OF AMERICA 94

B

G. H. BALES 108
THE BANTAM BALL BEARING CO. 120
BUSSMANN MFG. CO. 91

C

CLARK CONTROLLER CO. Cover 1
THE CLEVELAND CRANE & ENGINEERING CO. 110
CUTLER-HAMMER, INC. 111

E

THE ELECTRIC CONTROLLER & MFG. CO. 93

F

FARREL-BIRMINGHAM COMPANY, INC. 117
FLINN & DREFFEIN CO. 104

G

GENERAL ELECTRIC COMPANY 106-Cover 4

H

HYATT ROLLER BEARING COMPANY 105

I

I-T-E CIRCUIT BREAKER COMPANY Cover 3

L

LADD EQUIPMENT CO. 108
LEWIS FOUNDRY & MACHINE CO. 96

M

THE MARTINDALE ELECTRIC CO. 117
McGRAW ELECTRIC COMPANY 91
THE McKAY MACHINE COMPANY 104
MESTA MACHINE COMPANY 98
THE MORGAN ENGINEERING COMPANY 103

N

NATIONAL CARBON COMPANY, INC. 101-114
THE NEW DEPARTURE MFG. COMPANY 97
NEW YORK & NEW JERSEY LUBRICANT CO. 115
THE NICHOLS-LINTERN COMPANY 114

P

PENNSYLVANIA TRANSFORMER CO. 118
PERIN ENGINEERING COMPANY, INC. 116
POOLE FOUNDRY & MACHINE CO. 108

R

RAILWAY & POWER ENGINEERING CORPORATION, LTD. 114
REITZ SALES CO. 108
RELIANCE ELECTRIC & ENGINEERING CO. 112-113

S

SKF INDUSTRIES, INC. 95
STIMPLE & WARD CO., INC. 115
SURFACE COMBUSTION CORP. 99

T

THE THOMPSON ELECTRIC CO. 116
THE TIMKEN ROLLER BEARING COMPANY 109
THE TOOL STEEL GEAR & PINION CO. 100
THE TRUMBULL ELECTRIC MANUFACTURING COMPANY 102

U

UNION CARBIDE AND CARBON CORPORATION 101-114

W

THE WEAN ENGINEERING CO., INC. 104
THE WELLMAN ENGINEERING CO. 107
WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY Cover 2

Heat Transfer To The Open Hearth Bath

By WILLIAM C. BUELL, JR.,
Engineer,
Cleveland, Ohio.

Presented before Combustion Engineering Division of the A. I. & S. E. E., at the Twenty-ninth Convention in Pittsburgh, October 19, 1933.

WILLIAM C. BUELL, JR.

The basic open hearth furnace is endowed with but a single collective function. This may be stated as the melting and/or refining of the appropriate materials to a predetermined analysis and developing such a temperature as will permit the casting of the liquid steel into suitable ingots.

All of this must be accomplished within a furnace which consists of a shallow hearth enclosed in a refractory structure, through the effect of heat which is developed in part through chemical reactions within the charge, and, finally, through the extraneous application of oxidized fuel.

In the largest furnaces the length of the hearth or bath will not exceed fifty feet, while in tonnage furnaces the area of the bath through the surface of which the extraneous heat must pass will range from 400 to 750 square feet, the latter figure representing the maximum area of contemporary design.

From figures to be presented it will be seen that modern tonnage furnaces produce from nine to eighteen tons of steel ingots per average operating hour. If a low carbon practice with about 45% hot iron is assumed it may be calculated that some 700,000 to 1,000,000 B.t.u. of extraneously created heat must enter the bath in order to process each ton of steel poured.

A total of perhaps 2,900,000 B.t.u. is required to melt, refine and pour a ton of steel but of this approximately 2,100,000 B.t.u. are developed by the exothermic reactions of the process, leaving 800,000 B.t.u. to be supplied from the products of combustion, which is the value taken as a basis of this discussion. This value might equally well be higher or lower for in common with all other data entering open hearth research it is subject to so many variations and modifications as to preclude the establishment of any definite value.

As 5,000,000 or more B.t.u. as primary fuel must be oxidized for each ton of steel produced, while but 800,000 B.t.u. actually enter the bath, except in very good practice, it is clearly evident that any factors which might tend to increase the rate of heat transfer to the bath, and, thus, increase the apparent thermal efficiency of the process, are worthy of much and careful investigation.

It is the purpose of this paper to present a line of reasoning that, if followed to a successful conclusion, may be instrumental to a more efficient process.

Probably, the best comparative index of furnace ability is its production of steel, tons per hour, over a considerable number of heats, or better, an entire campaign, reduced to a common unit of comparison such as: tons of steel per one thousand square feet of bath area per hour, although, if pushed for high tonnage a furnace will show high rebuilding, and, perhaps, high fuel costs that will possibly cancel any economic advantages of high production.

The data of Table I are included to indicate essential comparative figures relative to bath areas—production ratios, and which will be used in the development of a hypothesis of heat flow effects in the laboratory of an open hearth furnace.

In the table, furnaces fired by producer or mixed gases are grouped, as are those fired by the other common fuels,—tar, oil, coke oven or natural gas, etc. This on the grounds that more than one and one-half times the volume of furnace gases are developed from the combustion of the fuels of the first specified group, as compared to the latter group, and results will be found to vary somewhat in the same order.

The furnaces listed are from installations in 12 different plants and the production data, columns a and b, are the average of from not less than 50 to more than 700 consecutive heats.

The bath areas, column c, are computed by a standardized method, so as to be truly comparative.

The methods by which columns d, e and f have been computed will be obvious, and the values of either of the two latter are correct comparative media of the productive capability of any furnace, to any other units, regardless of individual size. The areas of column f constitute the receiving surface values upon which this study is developed.

Table II presents a further development of data to the ultimate of the basis of this study. In this, the areas per ton of steel produced per hour, column a, are those of column f, Table I.

TABLE I

BATH AREA — PRODUCTION — VARIOUS FURNACES

FURNACE	STEEL PRODUCTION GROSS TONS		AREA OF BATH SQ. FT.	SQ. FT. OF BATH PER TON OF STEEL	TONS OF STEEL PER 1,000 SQ. FT. OF BATH PER HOUR	SQ. FT. OF BATH REQUIRED PER TON OF STEEL PER HR.
	PER HEAT	PER HOUR				
	a	b	c	d	e	f
PRODUCER OR MIXED GAS FIRED FURNACES						
A	156.3	13.00	468.9	3.00	27.7	36.7
G	137.6	12.05	500.6	3.64	24.1	41.6
J	161.5	13.27	681.1	4.22	19.5	51.3
K	164.6	13.72	641.7	3.90	21.4	46.7
L	153.3	13.32	653.0	4.26	20.4	49.0
N	260.5	16.70	585.1	2.25	28.5	35.0
O	312.5	18.97	776.5	2.48	24.7	41.0
FIXED FUEL FIRED FURNACES						
B	124.9	9.93	454.9	3.64	21.8	45.9
D	118.6	9.16	514.4	4.31	17.8	56.2
E	160.5	11.47	494.1	3.08	23.2	43.1
F	151.0	10.47	657.9	4.35	15.9	62.8
H	128.2	10.42	503.9	3.93	20.9	48.4
I	187.6	17.05	641.7	3.42	26.6	37.7
M	224.7	13.30	576.2	2.57	23.1	43.4
P	229.0	13.43	599.5	2.62	22.4	44.7

We have before stated that we would assume the value of 800,000 B.t.u. as the quantity of heat to be transferred to the bath in order to make one ton of steel, and column b is accordingly developed by dividing this value by the areas of column a. It should be particularly noted that the figure thus found does not include the heat passing through the bath and the refractories to satisfy the bottom radiation requirements. For the furnaces listed this would range from about 1,100 to 2,500 B.t.u. per square foot of bath area per hour, depending on the depth of the slag and metal and the refractory construction, or from five to perhaps ten per cent more than the values listed. The value is omitted as a variable, non-essential to the purpose of this discussion.

The determination of the heat transfer or flow coefficient necessitates the establishment of a temperature differential between the furnace gases and the bath. This has been accomplished graphically as shown in Figure 1, and the value of 700° is presumed to be the average differential over the elapsed time of the heat. It is very much greater during the melting period and considerably less during the refining and finishing periods. It is difficult, if not impossible, to arrive at a representative figure in any other way. Accordingly, 700 as taken, divided into the values of column b develops the coefficient of transfer from the furnace gas to the bath, column c.

The origin of the dimension, length of bath, column d, is, of course, obvious.

The furnace gas velocity values, column e, are taken from and are as developed by methods explained in our recent articles in the magazine "Steel". They are computed as at 32°, and as completely filling and flowing at a uniform velocity through the transverse furnace section over the hearth.

The time of the furnace gas contact with the bath, column f, is obviously found by dividing the values of column d by those of column e.

The fuel rates, column g, are averages covering the number of heats taken as a basis of the data in the original study.

It is interesting to note that the average transfer coefficient, the average gas velocity, and the average contact time is 27, 9.8 feet and 4.5 seconds, respectively, for the first group as against 24, 6.35 feet and 6.7 seconds for the second group. The apparent difference of transfer effect in favor of the raw gas fired furnaces will likely be found from the action of greater mass effect.

The primary purpose of this paper is a consideration of the effects of furnace gas velocity and the gas contact time on the economic operation of the open hearth furnace. It is believed the question is of great importance and that future economies must be accomplished through an understanding of the principles involved and their effective utilization. In presenting the text to follow we realize the hypoth-

TABLE II

GAS FLOW AND HEAT TRANSFER RESULTS

FURNACE	SQ. FT. OF BATH PER TON OF STEEL PER HR.	HEAT TRANSFER * TO BATH B.T.U PER SQ. FT. PER HR.	TRANSFER COEFFICIENT B.T.U. PER SQ. FT. °t△ Per Hour	LENGTH BATH. FEET	FURNACE GAS VELOCITY. FT. PER SEC. AS AT 32°	TIME OF F'CE. GAS CONTACT. WITH BATH SECONDS.	FUEL RATE MILLION B.T.U. PER TON OF INGOTS
	a f - Table I	b 800000 a	c b 700	d	e	f d e	g
PRODUCER OR MIXED GAS FIRED FURNACES							
A	36.7	21800	31	36.5	11.7	3.1	5.393
G	41.6	19230	28	40.0	8.1	4.9	4.500
J	51.3	15590	22	46.0	9.1	5.0	4.840
K	46.7	17130	24	46.0	8.5	5.4	4.537
L	49.0	16330	23	46.75	8.9	5.3	4.700
N	35.0	22860	33	40.00	11.9	3.4	5.049
O	41.0	19500	28	47.00	10.4	4.5	4.877
FIXED FUEL FIRED FURNACES							
B	45.9	17430	25	34.0	4.7	7.2	4.947
D	56.2	14230	20	41.0	8.2	5.0	5.250
E	43.1	18550	26	39.5	6.0	6.6	5.112
F	62.8	12740	18	50.0	6.4	7.8	5.188
H	48.4	16530	23	39.0	5.8	6.8	5.147
I	37.7	21220	30	46.0	8.1	5.7	4.500
M	43.4	18420	26	40.5	5.6	7.2	4.881
P	44.7	17900	26	42.0	6.0	7.0	5.014

*THIS VALUE DOES NOT INCLUDE HEAT RADIATED THROUGH BOTTOM.

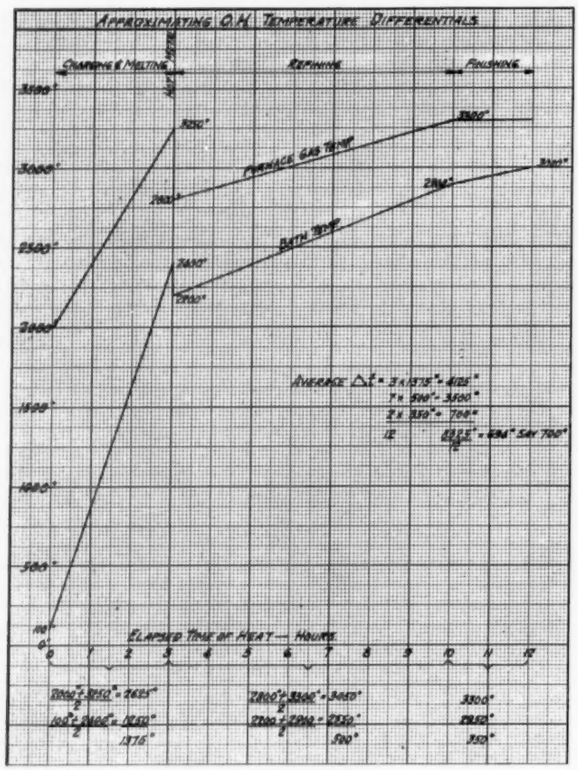


FIG. 1

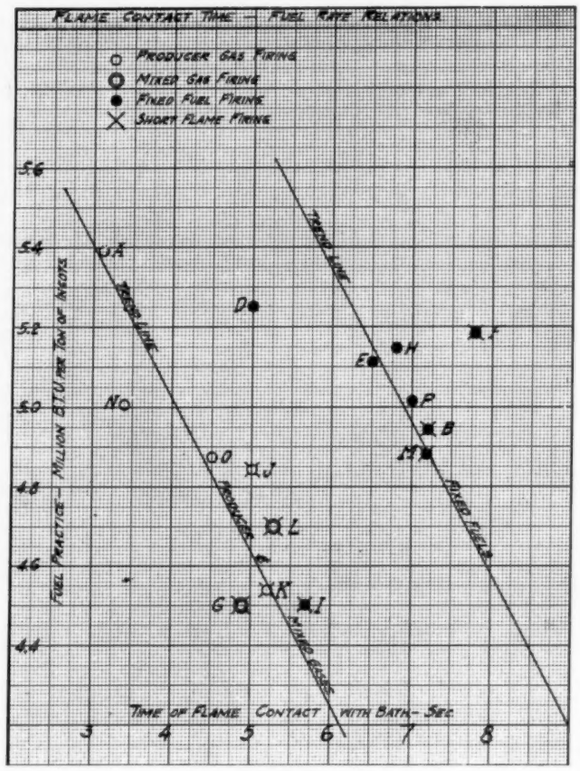

Flame Contact Time — Fuel Rate Relations
Producer Gas Firing
Mixed Gas Firing
Fixed Fuel Firing
Short Flame Firing
Fuel Practice — Million BTU per Ton of Ingots
Time of Flame Contact with Bath — Sec.

FIG. 2

esis as developed is open to severe criticism, especially, as certain data will be contradictory, and, further, as we are unable to offer a technical solution that cannot be successfully criticised in detail. We are, however, certain that no substitute may be offered that will not be open to the same objection, and we, accordingly, offer this with the underlying idea that as more of us give the matter the thought of which it is worthy, and make our thoughts known, the quicker we will arrive at a rational solution of the problem, which may be stated as: "What is the best velocity or time of contact of the furnace gases passing over the hearth?"

In primarily treating of this subject as an effect of velocity rather than as a change of the transfer rate of convested heat we realize some may criticise on the ground that we overlook or ignore the basic theory involved. As a matter of fact we do neither, and, in extenuation of our method of approaching the problem, wish to emphasize that treated by our method the mathematics of the transfer effects are simple, in concrete values and easily understandable, whereas, were it attempted to treat the subject by the application of the common but little understood mathematics of radiation and convection this treatise would consist largely of a mass of calculations of little general interest and doubtful accuracy. In this the attempt is made to present an elementary method of calculation, of wide practical application, that, in view of the variables entering the problem, develop an accuracy commensurate with the general technology of the practice.

We present in Figure 2 a chart in which we have placed the fuel practice of the several furnaces against the time of flame contact and have plotted trend lines for the groups of furnaces fired with the

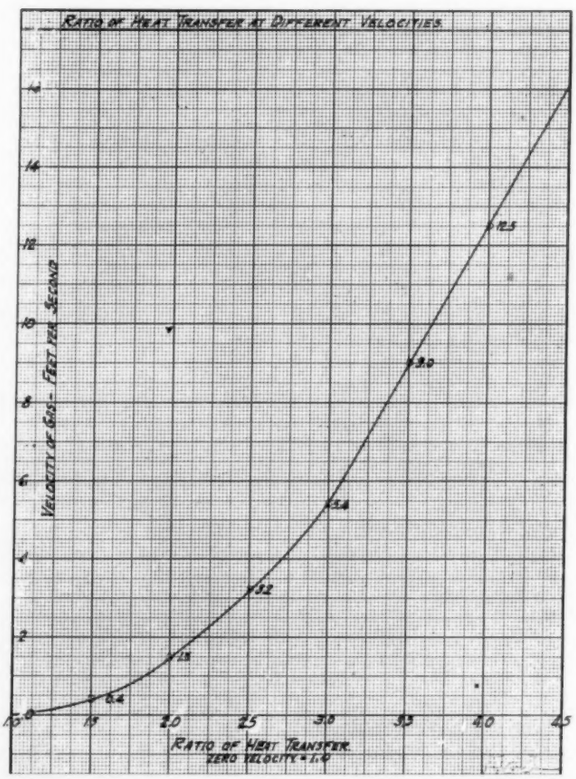


FIG. 3

two classifications of fuel. The trend line for the producer or mixed gas fired furnaces, A, G, J, K, L, N and O, falls remarkably and consistently close to the actual results, while for the fixed fuel fired furnaces inconsistencies, which, like the poor, are ever with us, appear in the cases of furnaces D, F and I.

The following explanations of the inconsistencies of these three furnaces are offered in the hopes they may be convincing. Furnace D, originally built as a 90-ton furnace is regularly producing at more than 120 tons. Were it operated at its original rating the gas contact time would proportionately increase to more than six feet per second and without doubt there would be an appreciable decrease in the fuel rate. Furnace F is producing less than 150 tons, which is but 60% of the production for which designed. On account of the great length of bath it is thought that at the low operation added fuel is necessary to keep the bath at the outgoing end at sufficient temperature. Were this unit to be operated at such a greater tonnage as to develop a contact of about seven seconds it is believed the fuel rate would fall to the vicinity of 5,000,000 B.t.u.

Furnace I is regularly operated at about 25% greater tonnage than as designed. As designed the contact time was to be about 7.5 seconds. The fine fuel rate of this unit under high tonnage operation probably accrues from the especially long throat and large capacity checkers included in the original design. As high tonnage has been necessary from this furnace during its entire life, unfortunately, no opportunity has been presented to develop supporting check data at normal ratings.

In considering Figure 2 the value of short flame firing as an aid to fuel economy is at once apparent. This is usually accomplished as a matter of design in the newer furnaces, but, in any event, it is assumed the best combustion possible in a furnace unit for a given practice is now ordinarily practiced. This will mean that the outgoing furnace gases near the top of the downtakes will range from perhaps 3 to 5% O_2 during melting, to 2 to 4% CO during the boils and refining and that but traces of either of these gases will show during finishing. Thus the quantity of the furnace gases as represented in volume will not be a factor materially affecting transfer rates.

Again, the trend lines of Figure 2 show an equal fuel practice and its contingent transfer effects will be secured from the raw fuels with a shorter time of contact. This, as before mentioned, is believed to be due to mass-volume difference.

TABLE III

COMPARISON OF VELOCITY EFFECTS ON HEAT TRANSFER

HEAT TRANSFER RATE B.T.U. per Sq. Ft. or °$t\triangle$ Per Hour	GAS VELOCITY AS AT 32° FT. PER SEC.	HEAT TRANSFER RATIO	TIME OF GAS CONTACT SECONDS	TRANSFER TIME FACTOR
a	b	c	d	e
Table II	Table II	Fig. 3	Table II	a-d
AVERAGE FOR 7 PRODUCER AND MIXED GAS FIRED FURNACES.				
27	9.8	3.6	4.5	121.5
AVERAGE FOR 8 FIXED FUEL FIRED FURNACES.				
24	6.35	3.1	6.7	160.8
IF TIME OF GAS CONTACT IS INCREASED TO 150% THE RESULTS WILL BE AS BELOW.				
f	g	h	i	j
$\frac{a-h}{c}$	$\frac{b}{1.50}$	Fig. 3	d-150	f x i
FOR PRODUCER OR MIXED GAS FIRED FURNACES				
23.5	6.53	3.13	6.25	146.7
FOR FIXED FUEL FIRED FURNACES.				
21.7	4.24	2.80	10.05	218.0

TABLE IV.

PRINCIPAL DIMENSIONS ON TRANSVERSE SECTION—VARIOUS FURNACES—REFER TO FIG. 4.

FURNACE	WIDTH		HEIGHT FORE PLATE TO CROWN	AREA A, SQ. FT.	PRODUCTION TONS OF STEEL PER HOUR	AREA SQ. FT. PER TON of STEEL PER HOUR
	AT BOTTOM	AT SKEW				
PRODUCER AND MIXED GAS FIRED FURNACES.						
A	14'-0"	16'0"	7'3½"	104.65	13.00	8.05
G	13'-6"	17'0"	6'8"	97.89	12.05	8.11
J	16'-0"	20'9½"	7'9"	123.595	13.27	9.31
K	15'-0"	20'0"	6'7½"	125.26	13.72	9.13
L	15'-0"	19'0½"	7'0"	106.105	13.32	7.96
N	16'-0"	19'6"	7'3"	124.10	16.70	7.43
O	18'-0"	22'0"	8'1½"	155.875	18.97	8.22
FIXED FUEL FIRED FURNACES.						
B	14'9"	19'1"	7'4¾"	113.8	9.93	11.46
D	13'6½"	18'1½"	6'7"	99.282	9.16	10.84
E	13'6"	16'8"	7'4½"	106.761	11.47	9.31
F	14'0"	16'0"	7'0"	96.155	10.47	9.18
H	14'0"	19'4½"	6'7"	100.105	10.42	9.61
I	15'0"	18'6"	7'1½"	103.125	17.05	6.05
M	15'6"	19'10½"	6'10½"	122.436	13.30	9.21
P	15'5"	20'6"	6'10½"	117.55	13.43	8.75

Further, the trend lines certainly indicate conclusively that a lower fuel practice will be secured if the velocity of the furnace gases over the hearth are reduced to give a longer time of contact.

It is rather interesting to surmise and may be quite profitable to investigate to what extent a reduction of fuel practice might follow an increased gas contact time. Extension of the trend lines would supply grounds for the prophesy that 4,000,000 B.t.u. practice would result if the gas contact time was about seven seconds in the raw fuel fired furnaces and nine and a half seconds in furnaces fired with fixed fuels.

Before discussing the methods by which the furnace gas velocity may be reduced it will be well to consider the effect that lowering the furnace gas velocity will have on the heat transfer rate.

The often quoted rule that the heat transfer rate increases with the velocity of the gas is, of course, true. However, if the dimension of time or some other qualifying factor is not appropriately applied, a totally erroneous impression of the meaning of this rule may result.

In Figure 3 a curve is offered giving the ratio of heat transfer from a hotter gas to a cooler body. This curve is developed as a mean of the findings of several investigators, any of whom find values different from the others.

This curve indicates that from a basic transfer ratio of 1.0 in still gas the values increase until the transfer ratio is about 4.5 in conjunction with a gas velocity of 16 feet per second, a considerable variation.

The average transfer rate for the seven raw fuel fired furnaces, column c, Table II, may be found as about 27 B.t.u. per ft.²/hour/degree differential, the furnace gas velocity, column e, as about 9.8 feet per second, and the time of gas contact with the bath

as about 4.5 seconds. Similar data for the fixed fuel fired furnaces would be 24, 6.35 and 6.7. These several values are carried to Table III and noted appropriately under columns a, b and d. The heat transfer ratio is now found, taking into account the gas velocity, by the use of Figure 3 and the correct value entered under column c.

If the heat transfer rate is multiplied by contact time the arbitrary time-transfer value, column e, is found which includes all the vital factors necessary to make a comparison of a related condition.

The purpose of the figures of Table III is to demonstrate that reducing the velocity of the furnace gas will, instead of lessening the total heat transfer, increase it very materially.

Assume that in both the above cases the time of gas contact is increased to 150%, or to 6.25 and 10.05, seconds respectively. To increase the time of contact the gas velocity must be decreased proportionately and the heat transfer ratio will also diminish.

The figures developed in the lower half of Figure 3 cover the condition described.

From this it will be noted that reducing the gas velocity in the raw fuel fired furnaces will actually increase the transfer of heat to the bath in the order of 146.7/121.5, or from 1.0 to 1.2, and in the case of the fixed fuel fired furnaces in the order of 218.0/160.8, or from 1.0 to 1.36.

This is the case for the thermo-physics of a lower furnace gas velocity-longer time of bath contact, and a reduction of the fuel rate.

To secure any reduction of the gas velocity primarily means the increase of the transverse area over the hearth, in proportion to the velocity reduction desired, although in the case of the raw fuels some betterment may be secured by a method of more rapid mixing of the fuel and air in conjunction with some increase of area, and lower dynamic heads on the fixed fuels entering the throat may also assist.

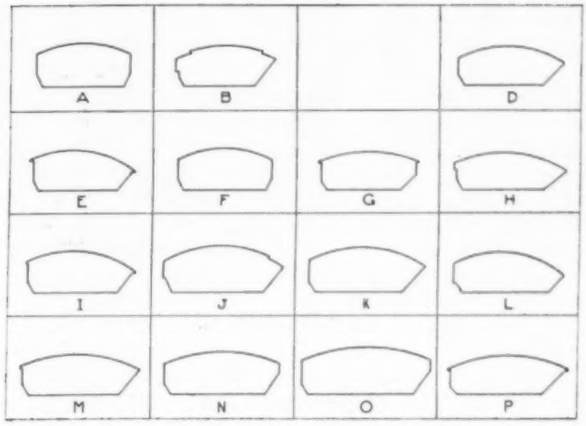
So far as existing furnaces are concerned a material increase of transverse area can only be accomplished by raising the furnace roof.

It is probable now present mechanical limits will govern what may be accomplished in this direction, although it is our impression that such limitations which often appear insurmountable may be mitigated by a correct approach to the problem.

In Figure 4 we present the laboratory contours of the furnaces forming the basis of this discussion, and, in Table IV details as to width, height, area, and area per ton of steel per hour.

These are presented without comment with the idea that they may be of interest to any who might care to give further thought or analyses to this vital subject.

There is one item of upkeep cost which will react most favorably as a result of the slower velocity from the enlarged cross section. This is the roof life. Loss of thickness of the hot side of the roof from the effect of temperature will be less on account of the greater height while erosion of the back and front wall from gas born solids will decrease materially. The incorporation of the higher roof will also expedite charging, particularly where large quantities of light scrap are used.



For details see Table IV.

FIG 4

Discussion

▲

Discussion Presented by

W. N. Flanagan, Special Engineer, Carnegie Steel Company, Pittsburgh, Pa.

W. C. Buell, Jr., Engineer, Cleveland, Ohio.

L. Larson, Chief Engineer, Central Alloy District, Republic Steel Corp., Youngstown, Ohio.

J. L. Miller, Asst. Chief Engineer, Carnegie Steel Company, Youngstown, Ohio.

H. McClelland, Youngstown, Ohio.

H. V. Flagg, Asst. Combustion Engineer, American Rolling Mill Company, Middletown, Ohio.

G. A. Merkt, Manager, Combustion Control Dept., Morgan Construction Company, Worcester, Mass.

J. E. Dunn, Combustion Engineer, A. M. Byers Company, Ambridge, Pa.

M. J. Conway, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

Feodore F. Foss, Assistant to Chairman and General Metallurgist, Wheeling Steel Corporation, Wheeling, W. Va.

W. N. Flanagan: Not having prepared any discussion, I have very little to say. One thought that came to my mind towards the end of the paper,—"Why were the roofs dropped so low on many furnaces, unless for the elimination of high front and back walls?" In other words, the roof would be better protected, and there would be more chance for desired flame velocity, with a higher roof. The theory expounded by Mr. Buell looks good on paper. The only question (see curve 2) is why such a tremendous difference between the producer gas heat transfer time ratio and that of the fixed fuel flame, particularly when liquid fuels are considered. They usually go through the furnace at a relatively high velocity, due to the driving effect of the atomizing medium and probably have the same flame temperature as producer gas. Is the data from which the curves were plotted based upon actual furnace velocities or upon calculated velocities for maximum heat transfer in the various furnaces?

W. C. Buell, Jr.: Answering Mr. Flanagan's several questions: the values used as a basis for the paper are all real figures from actual operations.

The usual open hearth roof is approximately developed to the sixty degree included angle which incidentally should never be more. However, there is no serious objection to decreasing the angle somewhat which will increase the spring of the roof. With more spring the skews may be set lower thus lessening the height of the front and back walls. Thus, conversely with careful design the roof crown may be raised without increasing the height of the front and back walls unduly.

Anyone who has observed the flow of an oil flame (for instance) over the open hearth bath will know that the assumption that the combustion gases expand to fill the space over the hearth and then travel outward at a constant velocity is to some degree incorrect. It is, however, impossible to treat of the subject rationally without making this and several other suppositions of a similar nature.

As explained in the body of the paper the higher coefficient developed in the case of producer gas as compared to the fixed fuels is undoubtedly the result of the greater mass-density effect in the case of the former fuel.

It is the principal idea of the paper to show that slowing down the furnace gases while traveling over the bath will increase the heat transfer rate.

W. N. Flanagan. That explains the situation very thoroughly. With a higher roof, the effect of radiation should not come in, because all the radiated heat is confined by the roof and side walls. (neglecting the heat losses through the refractories)

W. C. Buell, Jr.: In a number of instances we have found that raising a roof has reduced fuel materially.

L. Larson: In my opinion too much emphasis has been laid on relation of velocity of gases to rate and magnitude of heat transfer to the bath. Inasmuch as the heat transmitted by convection and conduction is relatively small compared to that transmitted by radiation directly from flame to bath or indirectly from flame to hearth refractory surface to bath, such factors as degree of air preheat, temperature and character of flame, ratio of hearth refractory surface to bath surface and rate of flame propagation must necessarily play a predominating part in rate of heat transfer and performance of the Open Hearth Furnace. Velocity of gases then becomes a function of rate of heat input commensurate with the ability of flame to impart, or bath to absorb, heat above permissible exit temperature of gases from hearth.

I am not prepared to offer any conclusions, myself, but any logical approach to improvement of heat transfer in the open hearth furnace must recognize the above factors.

J. L. Miller: This paper has been very interesting and while I have very little in the way of remarks, one thing has occurred to me which has made the results a little difficult to understand. The percent of excess air which exists in each case shown appears to be about a constant. Was this an assumption or from actual tests?

W. C. Buell, Jr.: The same combustion conditions are taken to hold throughout. In the newer plants and in the older plants with good refractory practice, leakage through the brick work is almost totally absent. Under these conditions combustion practice is nearly a constant and during the melt down and the early stages of a heat the outgoing furnace gas may be counted upon to show not over five per cent oxygen and no combustibles, and during the boils and finishing two or three per cent carbon monoxide and but little oxygen. The fuel rates from which the data of this paper were developed were calculated from not less than fifty to over eight hundred consecutive heats.

J. L. Miller: The actual tests were then corrected by calculations in order that these figures might be comparable with the same excess air?

W. C. Buell, Jr.: Yes, but complete data was included in the paper so that anyone who cares to do so may add that from other apparatus for comparison or may resolve the presented data for comparison when using a different method.

J. L. Miller: There is a considerable difference in the fuel ratios shown.

W. C. Buell, Jr.: True, but when we average results from fifty or eight hundred heats we would be essentially correct.

J. L. Miller: I have only this further comment to make, that if this theory as set forth of raising the roof to effect greater heat transfer then we certainly have greater possibilities relative to O. H. furnace roof insulation. This ought to look very interesting to the insulating people.

W. C. Buell, Jr.: This is entirely correct.

H. McClelland: I don't know that I can add very much to what has already been said. I do feel, however, that raising the roof without taking other things into consideration such as class of scrap used, fuel and port construction will result in longer heat time. I also feel that the ideas advanced by the engineers in meetings such as these will undoubtedly help the operating man to solve his problems.

H. V. Flagg: Mr. Buell's paper strikes me as being a very rational and logical application of open hearth furnace operating data to a purely theoretical problem. My own experience checks his conclusions. A combination of furnace contour, port shape, furnace pressure, and air-fuel velocities, to hold the flame in the furnace as long as possible and still maintain proper bath coverage, should give good operating results.

G. A. Merkt: I rather enjoyed Mr. Buell's paper, because he has the courage to come out publicly with certain trends of thought that we have been trying to utilize and preach, particularly on the other end of the open hearth system, that is in the regenerative end. We have always maintained that time has something to do with the transfer of heat. The factor used states that so and so many B.T.U.'s per degree difference, per square foot, per hour, or second, whichever way you want to make it, pass along and usually that hour or second is neglected, because it is submerged in the general function of that factor. If we consider it from this new point of view, we ought to come to the conclusion that something might be done by allocating the time element perhaps in a little different way, and I think that Mr. Buell has given us a very good thought in that respect.

J. E. Dunn: There is one point in Mr. Buell's

paper that was not very clear to me. He seemed to lay great stress on the correct flame velocity or in other words heat transfer by convection in the open hearth furnace.

I think, everybody is in agreement, that the relation between heat transfer by convection is so far out of proportion with heat transfer by radiation, that when we consider fuel efficiencies or melting efficiencies in relation to the area and depth of bath we see that so little has yet been accomplished in the way of obtaining the maximum benefit of heat transfer by radiation, that more time and study should be spent towards perfecting the heat transfer by radiation.

Both factors, radiation and convection, are interconnected, i.e., to say there is a critical flame atmosphere where maximum efficiency by radiation can be obtained. Brick will only absorb heat so fast and radiate it so fast. When the maximum rate of absorption has been reached (and physical properties of brick limit this rate) no more can be obtained in the way of heat transfer by radiation. Further variations in flame velocity will possibly increase the percentage of heat transfer by convection but will materially decrease the heat transfer by radiation.

W. C. Buell, Jr.: Anybody who has researched in the open hearth has been overwhelmed with the number of variables included in any related problem. Fixed conditions are entirely absent, which means many assumptions must be included. To progress we must develop one problem or hypothesis, the latter term is best for it allows considerable latitude, at a time, and solve it to the point of greatest reasonable accuracy. If the particular problem is presented for discussion and poorly taken, let us discard it and go to something else more worthwhile. However, if it appears to possess some merit let us all think about it at least and possibly something of real value may be developed.

This paper is basically premised on the subject of convected heat and, also to some extent on the subject of radiated heat. Direct reference to either of these subjects is deliberately omitted as it appears impossible to apply the purely mathematically precepts of these subjects in such a way to develop a simple rational solution of the question presented.

M. J. Conway: Mr. Buell has given us a lot to think about in his paper. In it he has given as the primary purpose for its presentation, the consideration of the effects of furnace gas velocity and the gas contact time on the economic operation of the open hearth furnace and has made this study almost the chief consideration in design and operation of the furnace.

However, there are other factors entering into the efficiency of furnace operation besides gas contact times and velocity, such as design of checkers, pitch of ports, variation of temperature differential between gases and furnace charge, insulation, draft and combustion control, etc. These all have a bearing on tons per furnace hour while yet maintaining a fixed velocity through the furnace.

Perhaps the best way to test Mr. Buell's velocity and time contact theory is to change over from a producer gas fired furnace to an oil fired furnace, this as you know immediately results in a drop of required B.T.U. input at the port and decrease in the quantity of gases handled with an increase in tons per furnace hour. All of which does not exactly agree with the findings of Mr. Buell in his studies of velocities and gas contact times.

I hope that Mr. Buell will be able to continue his studies of this important phase of open hearth furnace operation and at some future date present data that will clear up some of now doubtful points.

Feodore F. Foss: In the paper on "Heat transfer to the open hearth bath," Mr. W. C. Buell, Jr., has presented calculations, basing on which he has made an attempt to connect heat transfer efficiency with the velocities of gases passing over the bath, or, inversely, with the time of gases' contact with the bath.

The deductions from this study are rather startling. It is intended to show, that lower fuel practice will be secured if the velocities of the furnace gases over the hearth are reduced to give a longer time of contact. Thus, the problem of heat transfer and respectively of fuel utilization seems to be solved by simply lowering of gas velocities in the melting space of the open hearth furnace.

From the elaborate description of the calculations made, it is seen, that data for 15 different furnaces have been gathered and that the results pertaining to "per heat" and "per hour" production represent averages of 50 to 700 heats. The data related to heat transfer, gas velocities and fuel rate, evidently, represent results of only one observation. This fact, of course, unfavorably affects the deductions made on the basis of gathered evidence.

It is regrettable also, that this comparison of furnace's capabilities was made on different furnaces working in different plants under different conditions of heating and melting.

As it is pointed out by the author himself, in the beginning of his paper, "the best comparison of furnace ability, probably, is its production of steel—tons per hour—over a considerable number of heats, or better, an entire campaign reduced to a unit of comparison."

In the manner this study was conducted, it leaves many doubts as to the comparability of conditions in which these furnaces have given results, taken for certain deductions.

The figures, representing velocities of gases, passing through the melting chamber of the furnace and determined as a quotient from division of the gas volume by the area of the furnace's cross section, have been used by some investigators as F. Told, Prof. Osann, Prof. Pavloff, some 40-30 years ago and nowadays have been left alone, as practically useless.

These velocities, calculated for different furnaces, cannot be compared on equal basis because they depend on many variables peculiar to every individual furnace. Among these variables are: changes in the temperatures of gases, fluctuations in air excesses used for combustion and particularly variation in moisture content of the gases and of the air. Combustion efficiency and infiltration of air in different parts of the furnace and particularly in the melting space, through the doors, tremendously influence the velocities of gases and their general travel through the furnace.

Assuming, that, in general, the composition of the charge in every case observed was more or less the

same, which is very doubtful, we cannot believe, that all heats had the same silicon, sulphur, and phosphorus content.

The comparability of heat transfer figures for different furnaces working in such conditions will be further jeopardized by the wide variation, which takes place, when one charge is worked under low volume of slag and another under a heavy volume. This hardly could have been avoided. The difference in the thickness of slag blanket, when 8% and 15% of limestone have been added, in certain furnaces, may reach 2-3 inches and it is evident, that heat transfer coefficients for such two heats will differ considerably.

At this time, it is appropriate to mention, that the method adapted by Mr. Buell to present the velocity figures reduced to feet per second, as at 32° F., although theoretically correct, leads to a wrong impression.

When it is said in the paper, that the time of gas contact with the bath was 4.5 or 10.05 seconds, it is an erroneous description of the physical phenomenon. At the temperatures prevailing in the furnace (about 3000° F.) this contact should be imagined as taking place during only about 0.8 second or 1.75 second.

Analyzing figures presented by Mr. Buell, we see, that very little interdependence could be found in them between the real index of heat transfer and duration of gas contact with the bath. In this case, the only real index of heat transfer is—ceteris paribus—the fuel consumption per ton of steel.

In the Table II, we find, that the highest fuel consumption of 5,393,000 B.T.U. corresponds to the velocity of 11.7 feet per second in one case and 5,250,000 B.T.U. corresponds to 8.2 feet per second in another case. The nearest high fuel rates of 5,112,000 and 5,147,000 correspond to 6 f. p. s. and 5.8 f. p. s. respectively. That means, that nearly the same heat consumption was received at velocities varying about 100%. On the other hand, comparatively low fuel consumption of 4,500,000 B.T.U. corresponds to 8.1 f. p. s. in two cases and in another, of 4,881,000 B.T.U. (8% higher) the velocity is 5.6 f. p. s. (about 30% lower). This last figure means that short time of gases' contact with the bath gave one of the best fuel ratios.

No definite conclusion can be drawn from these results and it is easy to understand, "why." Because the phenomena of heat transfer in the open hearth furnace are influenced not only by the velocities of gases, but by several other factors, some of which we are not yet able to determine and some of which we even do not know how to determine.

If a study of one furnace would be made and heat transfer in different conditions of its operations would be determined, it can be safely predicted, that the general rule establishing interdependence of higher heat transfer efficiency with higher velocities of gases will be confirmed.

If we stop to think for a moment, that heat transfer in an open hearth furnace practically is in condition of parallel flow, and that the material in the furnace can be heated only to certain maximum temperature during one period between reversals, we will easily understand why lowering of the gas velocities in the open hearth furnace is theoretically and practically impossible.

We have to remember, also, that temperatures of combustion in the open hearth furnace are limited on both sides of heat transfer cycle. From one side, T_1—temperature of flame is limited by the refractories and to a certain extent, by the dissociation of certain gases (3300° F.) From another, T_2—temperature of steel and of slag must be above highest melting point of these substances (2900° F.) Therefore, the fall of temperature in the conditions of an open hearth furnace, which among other factors, determines the efficiency of heat transfer, is rather small (around 300° F.)

From this it is clearly seen, that the velocities of gases in the melting space of open hearth furnace cannot be lowered to any great extent, unless the operator wants to run under a constant threat of getting a salamander in the furnace.

The transfer of heat to the bath of an open hearth furnace hardly can be expressed by one figure or by one simple formula. The heating of the bath of molten metal is accompanied by a series of phenomena, several of which have not been studied enough to be even formulated. Among these, the phenomena of radiation of gases and radiation of products of combustion are outstanding. The next is the problem of speed of ignition and speed of combustion combined with the study of best radiation media, absorption degree of the flame, its thickness and temperature. All that naturally leads to the study of diffusion flame for the steel making furnaces and to one direction open hearth furnace.

Along those lines, as far as combustion phenomena are concerned, lies, to my understanding, the successful solution of further improvement of open hearth furnaces, of its process and product.

W. C. Buell, Jr.: I have been interested in reading the detailed criticism of Mr. Foss which was apparently presented in writing after the close of the meeting. I assume the thought and time he has spent on the preparation of his discussion is indicative of the interest in the subject presented. In replying I am taking the liberty of quoting from the original text of my paper, first,

> "In presenting the text to follow we realize the **hypothesis**[1] as developed is open to severe criticism, especially as certain data will be contradictory, and, further, as we are unable to offer a technical solution that cannot be successfully criticised in detail. We are, however, certain that no substitute may be offered that will not be open to the same objection . . . . "

and second,

> "In primarily treating of this subject as an effect of velocity rather than as a change of the transfer rate of convected heat we realize some may criticise on the ground that we overlook or ignore the basic theory involved. As a matter of fact we do neither, and in extenuation of our method of approaching the problem, wish to emphasize that treated by our method the mathematics of the transfer effects are simple, in concrete values and easily understandable, whereas, were it attempted to treat the subject by the application of the common but little understood

[1] F. & W. Standard Dictionary: hypothesis, def. A state of things assumed as a basis of reasoning, experiment, or investigation, an unsupported or ill-supported theory.

mathematics of radiation and convection this treatise would consist largely of a mass of calculations of little general interest and doubtful accuracy. In this the attempt is made to present an elementary method of calculation, of wide practical application, that, in view of the variables entering the problem, develop an accuracy commensurate with that of the general technology of the practice."

Thus, having anticipated criticism of an order such as offered by Mr. Foss I presume I may be reasonably excused from defending my **hypothesis**[1] against a purely technical attack.

In the past several years I have been fairly successful in the design and redesign of open hearth furnaces in which this simple method of calculation has been included, and my only excuse for offering it has been a desire to give the industry a simple method of producing operating economy that has worked without exception in the several cases in which it has been tried. Whatever the causes, the effects correspond to a considerable degree to the findings of the **hypothesis**[1]. I am perfectly willing, however, to discard it in favor of any other method that will be more nearly criticism free if it is sufficiently simple to be usable.

In closing I should like to add that in the past several years there has been a desire for increased tonnage and many furnaces have been regularly producing twenty-five or thirty per cent more steel per heat than that tonnage for which designed. This in effect is parallel to lowering of the roof.

Recently I have had the opportunity to observe the results of operating a furnace at reduced charges which in effect is parallel to raising the roof.

Over a campaign this furnace with its smaller charge produced more steel per hour and per campaign with about twenty-five per cent less fuel than did several other similar furnaces operating at the higher tonnage.

As the larger area over the bath and the lessened fuel input both contributed to a lower gas velocity over the hearth, we again seem to have fairly conclusive evidence as to the value of a lower velocity.

I wish to express my thanks to your Association for the opportunity to appear before you, and to the meeting for the interest accorded my paper.

Pack and Pair Heating Furnaces In Connection With Sheet and Tin Mills

By R. J. WEAN
President, The Wean Engineering Company, Inc., Warren, Ohio

Presented before the Combustion Engineering Division of the A. I. & S. E. E. at the Twenty-ninth Convention in Pittsburgh, Pa., October 19, 1933.

R. J. WEAN

One of the most interesting and useful contributions to the steel industry in recent years has been the development of modern continuous pack and pair heating furnaces for use in sheet and tin mills. The development of these furnaces in conjunction with the development of automatic feeding and catching tables has made it possible for an entire industry to be placed on a competitive operating basis when it appeared as though the old or conventional style sheet and tin mill was doomed.

Viewed from today's practice, it is difficult to understand why more adequate heating facilities had not been developed many years ago for use in sheet and tin mills.

Up until about 1926 or 1927—with the exception of the Continuous Pair Heating Furnaces of the pusher type—the industry still used in its entirety what are known as "in-and-out" furnaces and the only improvements made during that period were to enlarge the furnaces and to add more doors. This was done in order to handle larger tonnages produced on some sizes and to handle wider sheets as the demand for wider sheets increased.

The general cycle of operation in mills equipped with old style furnaces, which I shall refer to as the conventional type was as follows. Frequently the Pair Furnace was located at the back of the Sheet Heating Furnaces a distance of approximately 50 to 60 feet from the mill standing. Bars would be piled convenient to the door openings of the furnaces and the pairs charged into the furnace—preferably close

to the walls. The Pair Heater or Helper would remove the heated pairs from this furnace with tongs, drop the pair of bars to the floor and proceed on his journey to the Roughing Stand dragging the pairs on the floor behind him. He would throw the pairs on the fore plate and the mill crew would proceed to rough this material down to a gauge that had been more or less determined by practice as being the gauge that could be secured without too much loss of heat. This roughed down material would be matched and charged into one of the doors of the sheet furnace. These furnaces were normally located 20 to 30 feet from the mill stand and parallel to the mill. The sheet furnace might have 2, 3 or even 4 doors, depending upon the class of material being rolled and the amount of reduction they could obtain on each heating.

The material would be successively taken from the first door of the sheet furnace, rolled, re-matched or doubled, re-charged into the front end of the furnace and taken out at the same place. Normally, all of this work was done in heats of, say 15 to 20 packs or runovers.

Eminent writers have definitely stated that the amount of reduction and the number of passes given in sheet packs or bars was limited entirely to the temperature of the pack, and I am somewhat inclined to agree with this statement and believe that until quite recently sheet practice as carried on was an inheritance due largely to inadequate heating facilities.

A time study of a conventional sheet mill that produced six to nine tons of sheets in 8 hours reveals that less than 6% of the actual rolling capacity of the mill was being used. By that I mean the total amount of roll surface in feet per minute and considering that material could be in the mill at all times. That this inefficient operation should have continued for so many years seems almost unbelievable.

I could cite more specific details concerning the loss of heat in pairs and packs through the handling of tongs and dragging on the floor, as well as elapsed time between the time the material was taken from the furnaces and the actual placing of it into the mills, but unquestionably you are all familiar to a large degree with these details of operation and have observed these conditions. I, therefore, will not describe further the old conventional mill but will proceed with a review of the development of continuous furnaces.

To the best of my knowledge the American Sheet & Tin Plate Company, in their Gary Tin Mill, were the original developers of Continuous Furnaces. The original furnace was equipped with 8 burners for direct under and over firing. The fuel used was raw producer gas. The results were not satisfactory, and to overcome the difficulties a combustion chamber was put on the side of the furnace, new types of burners installed, which were located at the end and firing into combustion chambers parallel to the line of travel of the material. After some adjustment of the combustion chamber and the introducing of a "Radiant Gap" construction in order to keep down high temperatures in the combustion chamber, this furnace gave excellent heating results up to its capacity. The furnace was originally 30 feet long, was first extended to 34 feet and then to 38 feet. This furnace length gave very satisfactory results for the tonnage required and additional furnaces were installed.

The installation of these furnaces acted as a stimulus to the industry and attracted the attention of many Sheet and Tin Mill Engineers with the result that today in the Sheet and Tin Plate Industry there are installed a total of about 225 to 230 Continuous Pair and Pack Heating Furnaces of various types and sizes.

Illustration No. 1 has been prepared in an endeavor to show the various stages of development from the conventional furnace up to the present type. While the chart is drawn to indicate certain firing methods and a typical conveying method, I do not wish to infer that all furnaces are of this type but since we only had available drawings of the types of furnaces in which we are interested, we are of necessity forced to use this data.

The chart shows the general progressive development of pack and pair furnaces over the last seven-year period. Figure 1 shows the conventional old style mill having a continuous pusher type pair furnace and a single roughing mill stand roughing down for two finishing mills. The sheet furnaces shown are of the "in and out" type The flow lines for roughing and finishing are for a roughing and finishing mill arrangement where a wet rougher is not employed.

Figure 2 shows the short single line continuous pair or pack furnace which represents the original development.

Figure 3 shows how the single line furnace was lengthened and fired to meet the increased tonnage requirements when the mill stand was equipped with mechanical tables. This furnace could be either a pair or pack heating unit and the rolling stand could be either a two or three-high mill.

Figure 4 illustrates the double width open chamber type of furnace where available space would not permit the single line furnace as well as the fact that double width furnaces with independently operated conveyor lines permitted runovers to be handled on one side and finishing packs on the other which was desirable.

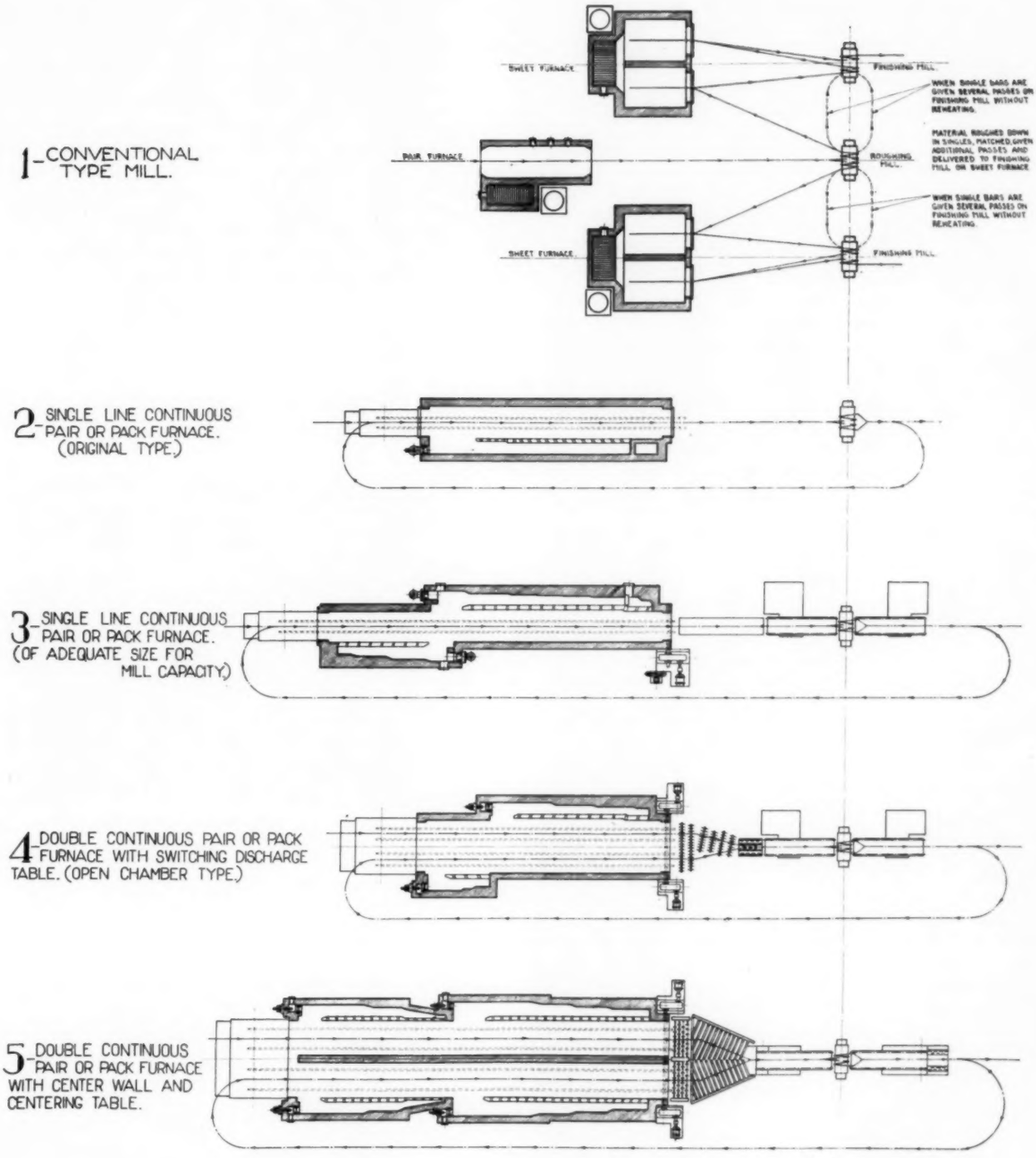
Figure 4 also illustrates the original switching type discharge conveyor used in connection with double width furnaces and mechanically equipped mills.

Figure 5 illustrates the double width center wall type of furnace with the centering type discharge table and I will deal with this type of furnace more fully in the latter part of this paper.

It is obvious that since any one of the furnaces could be used for either pairs or packs and the mill stand can be either two or three-high, that the best combination of roughing and finishing could be chosen based on existing conditions, available space and giving consideration to the product to be rolled; i.e., the line as illustrated in Figure 2 could be used as a rougher in combination with the finishing line as illustrated in Figure 5, etc.

What requirements must be met by a Pair and Pack Furnace?

1. Generally speaking, I might say any furnace must be capable of uniformly and thoroughly heating the material to the temperature required.
2. Tin Mill Furnaces can be built for practically a


1-CONVENTIONAL TYPE MILL.
SHEET FURNACE
FINISHING MILL.
WHEN SINGLE BARS ARE GIVEN SEVERAL PASSES ON FINISHING MILL WITHOUT REHEATING.
MATERIAL ROUGHED DOWN IN SINGLES, MATCHED, GIVEN ADDITIONAL PASSES AND DELIVERED TO FINISHING MILL ON SHEET FURNACE.
PAIR FURNACE
ROUGHING MILL.
WHEN SINGLE BARS ARE GIVEN SEVERAL PASSES ON FINISHING MILL WITHOUT REHEATING.
SHEET FURNACE
FINISHING MILL.
2-SINGLE LINE CONTINUOUS PAIR OR PACK FURNACE. (ORIGINAL TYPE.)
3-SINGLE LINE CONTINUOUS PAIR OR PACK FURNACE. (OF ADEQUATE SIZE FOR MILL CAPACITY)
4-DOUBLE CONTINUOUS PAIR OR PACK FURNACE WITH SWITCHING DISCHARGE TABLE. (OPEN CHAMBER TYPE.)
5-DOUBLE CONTINUOUS PAIR OR PACK FURNACE WITH CENTER WALL AND CENTERING TABLE.

SEVEN YEAR DEVELOPMENT OF PAIR & PACK FURNACES.

Illustration 1

constant demand as to sizes and material. Wide temperature variations are not required, the principal problems being proper heating, proper atmospheric conditions and proper control of the furnaces.

3. Sheet Mill Furnaces present a more difficult problem.
4. The surface of the packs must be free from deposits of soot, tar, ashes, carbon or other foreign matter.
5. The surface of the packs must not be scaled. In some instances they must not even show the slightest oxide.
6. The surface of the packs must not be scored or marked by the conveying apparatus.
7. The furnace must be capable of handling a full range of sizes and variable thicknesses of charged material.

On first consideration these specifications do not seem unusual but sheet heating temperatures vary, depending upon the quality and grade of sheets, from 1300 degrees Fahrenheit on up through the range of common black sheets, full finished sheets for auto body, enameling stock, electrical sheets, to the chrome and nickel products which are generally referred to as "stainless steel," some of which might require a temperature of perhaps 2000 degrees Fahrenheit.

The possible furnace operation must be flexible enough to handle all of these products. It must be flexible enough to handle these products at a rate varying from 12 to 15 tons in 8 hours up to 50 tons and sometimes more in 8 hours—all from the same furnace. The furnace must always be kept under control and to meet these variable and flexible conditions has been the principal problem of furnace builders.

Sheet mill practice has been revolutionized. Where formerly 8" bar was the standard material with which to start, sheet mills are now using 12, 14 and 16" bar which we term "wide thin bar." The amount of reduction taken per mill pass is no longer based on the old practice. The number of passes given to bars or packs to obtain certain reductions and gauges have been altered. Rolling temperatures have been changed.

General study discloses that in numerous plants old practices have been entirely discarded and new methods of rolling have been evolved.

Methods now employed in sheet rolling seem to indicate that the total cost of the product, the metallurgical results, and the proper surface finish—are the factors being used as a guide to determine sheet practice, and the furnace equipment must be flexible to the extent of making it possible to work out this practice.

In the earlier types of continuous furnaces runovers and finishing packs were heated in the same furnace chamber.

The effort to heat runover or finishing packs in an open chamber furnace whether it was single line or double line, resulted in a compromise heating temperature. Generally either the runovers were too hot and the finishing pack too cold, or the reverse. It was difficult to run furnaces having two thicknesses of material: for instance, the runovers might be a pack of 3's charged cold and the finishing pack might be a pack of 6's charged with about 500 or 600 degrees of temperature remaining in the pack.

It is obvious that in order to deliver both of these materials at the proper temperature the furnace must be of sufficient length to allow the material ample time to come to the desired temperature.

Higher heat impulse could not be put into one side or one line of material only. This led to a further study of the problem and resulted in the development of the double width center wall type of furnace as indicated in Figure 5 of the chart. This permits higher or lower temperatures for the material going through one side as compared to the other, and this we call proportional heating. Incidentally, it has been found in many instances that it is much better to run a different temperature for the runovers as compared to the finishing pack due to the difference in thickness of metal. This variation in temperature is helpful in maintaining the shape of the mill as well as in securing the desired elongation in a minimum number of passes. This construction also makes it possible to run the finishing side at a relatively low temperature in order to secure surface results, or even in some cases to secure the equivalent of a heat treatment in one side of the furnace.

Illustration 2

It is my personal belief that the center wall type of furnace has a greater capacity than the same size furnace without a center wall. This is partially due to the proportional heating feature, partially due to radiation from the center wall, but principally due to the fact that you can carry a higher temperature at the charging end of the side requiring a greater heat impulse without affecting the other line of material where the higher heat impulse would not be desirable.

It would seem advisable to devote some part of this paper to the subject of fuels, and here again I will confine myself to the statement of facts as they exist rather than attempt to point out the advantages or disadvantages of any of these fuels.

Furnace conditions are more easily controlled with a gaseous or liquid fuel; as originally stated the first furnace used raw producer gas. Many installations of raw producer gas were made where these facilities were available, and in the full finished industry many of the sheet companies installed producer gas facilities with the furnaces. For auto body work there seems to be a definite preference

for this fuel. Many common black sheet producing plants are using raw producer gas. A number of installations are still being put in on producer gas, in fact at this time some natural gas fired furnaces are being converted to producer gas.

Where there was no producer gas available, many furnaces were equipped for using natural gas and coke oven gas. Other plants used light oil.

During the last year many furnaces have been installed and equipped for the burning of 4 to 6 Baume oil or what is commonly called "heavy" oil. I believe this is a definite contribution to the industry for it has permitted the use of a fuel low in cost but having a high B.T.U. value.

From a practical standpoint, giving no consideration to the availability or combustion phase of the fuels, I believe that the following order of fuels shows the order of preference by the majority of sheet producers,—raw producer gas, heavy oil, light oil, natural gas, coke oven gas.

In March, 1932, at the Youngstown meeting of this

-TATA SHEET MILL AVERAGE MONTHLY TONNAGE-
COURTESY PERIN ENGINEERING CO.

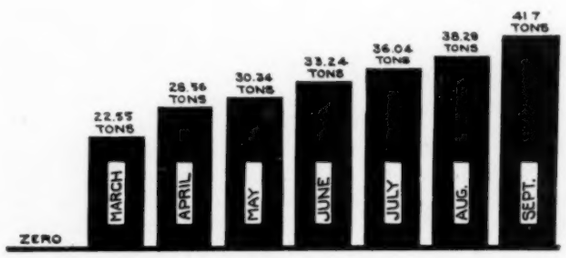


Illustration 3

Association I made the statement that furnaces were being installed equipped with burners for dual purposes, these burners to handle either oil or natural gas without any furnace changes other than minor ones in the combustion chamber wall and minor changes in the burners. The question was raised from the floor as to whether this was a practical proposition and I can only say that many furnaces are now successfully equipped and operated in this manner.

Illustration No. 2 shows a typical installation of a Continuous Furnace of the center wall type with a runout table and the tilting table on the roller's side. The catcher's table is not visible but was in operation on this unit. A return conveyor is shown on the right hand side carrying the runovers back to the charging end of the furnace.

Feeling it to be of general interest, I am pleased to show Illustration No. 3 which is a chart showing the operating results obtained on a Continuous Pack and Pair Heating Furnace and automatic table installation at the Tata Iron and Steel Company's plant at Jamshedpur, India.

This chart is reproduced through the courtesy of the Perin Engineering Company of New York and shows progressively the results obtained from the starting of the installation on March 11, 1933, up to the third week of September, 1933. The peak tonnages and average tonnage results obtained are remarkable, particularly so in view of the fact that this equipment is operated by native labor and white supervision is on the basis of one man for two mills. Mr. F. L. Estep, Vice President of the Perin Engineering Company, recommended and personally supervised the starting of this equipment, and to him should go the credit for the remarkable results that are being obtained.

The average production being obtained on this equipment in India is about five times the production that was formerly obtained on a conventional type mill in the United States. Total figures for September are not included in the chart, but for the month of September this installation operating 68 shifts produced 2,838 gross tons which is an average production per shift of 41.735 tons. During the month there was a total of 37 hours 37 minutes delay and it can readily be seen that if these delays could be cut down to a minimum that the production would be over 3,000 tons for the month for one unit. The material being produced is .92# per square foot sheets averaging 36" wide x 108" long which corresponds to a light 24 gauge in the United States.

When this mill was started in March, I have been told by a man we had out with Mr. Estep, that in the first three or four month period, they had the hottest weather and the worst working conditions they ever had in India, and Mr. Estep said, "He thought along about July or August, they would start hitting the ball." I don't know anybody that is making an average of 41.7 tons for eight hours in this country; and I think it is a remarkable record for any place; but it simply bears out something we have been saying for a long time, that sometimes we know too much about the job. The sheet rollers in the mills here know too many things that can go wrong and they would be a lot better off if they could have direct supervision of the mill, but the mill operators who do the actual mechanical work really don't have to be highly skilled men. It has been reduced to a supervising problem. I think possibly Mr. Estep is here and I heard that he had a cable giving him the average for either last week or the week before and I don't want to state the wrong figures. If he is here, I hope they call on him and ask him what it was.

In conclusion, I would say that the Sheet and Tin Mill wishing to give consideration to furnaces should survey the available fuels and space for the installations. If there is some question as to the availability of a single fuel on a price basis that would be favorable, it would be advisable to consider equipping the furnace with a dual fuel system; i. e., oil and natural gas. This can be done with little extra expense and places the producer in the very favorable position of being able to shift to the lowest cost fuel at any time.

In the final analysis, there are two things of major importance to the producer: first, quality of heating, and, second, lowest ultimate cost. Some of the producers have a third problem which is that the equipment must be capable of handling a wide variety of sizes, gauges and finishes. It is not unusual for a mill to have scheduled electrical sheets, enameling stock, common black sheets, single pickle and full finished, these to go through the same furnace and to be rolled on the same mill within 24

hours. Needless to say, if this producer has a single purpose furnace he is in a very unfortunate position as either he can not roll some of the materials mentioned or he will obtain quite mediocre results and probably a very high scrap loss. This third requirement of flexibility has removed furnaces from the realm of burner and conveyor design to one of utility.

The possibility of higher mill speeds permitting the production of greater tonnages as well as the recent installation of coal fired continuous pair and pack furnaces indicate that there may be still further developments in pair and pack heating furnaces in the future.

Discussion

▲

Discussion Presented by

F. L. Estep, Vice President, Perin Engineering Co., Inc., New York, N. Y.
F. E. Leahy, Fuel Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.
C. H. Verwohlt, Plant Engineer, Wheeling District Mills, Wheeling Steel Corp., Wheeling, W. Va.
R. J. Wean, President, The Wean Engineering Company, Inc., Warren, Ohio.
H. V. Flagg, Asst. Combustion Engineer, The American Rolling Mill Company, Middletown, Ohio.
F. Oppenheimer, Asst. Engineer, Apollo Steel Company, Apollo, Pa.
G. J. Hagan, Hagan Corporation, Pittsburgh, Pa.
T. B. Bechtel, Engineer, Electric Furnace Company, Salem, Ohio.
W. E. Blythe, Engineer, Driver-Harris Company, Detroit, Mich.
N. B. Ornitz, Engineer, National Alloy Steel Company, Blawnox, Pa.

F. L. Estep: I don't know exactly what you gentlemen might be interested in, so I will just tell something about the mill and its performance and answer any questions I can that you gentlemen may ask.

In the first place, the unit consists of two hand roughers, fed with one double width pair furnace, a 50 ft. by 8 ft. mechanical roller type doubler for doubling the hot packs after one pass run over on the finishing mill; a driven conveyor from the doubler to the charging end of the pack furnace, on which there are placed alternately, packs of matched threes from the rougher and doubled packs of sixes. The pack furnace is double width, without a dividing wall, 55 ft. long by 8 ft. wide. The left side carries the packs of threes, the right side of the furnace carries the packs of sixes.

The gauge rolled is their 24 gauge for galvanizing. There are only two widths rolled on the mill, viz; to shear 36 inches wide for plain galvanized and 34¾ inches for corrugated. The process of rolling is one pass on threes, thrown off on the back side, doubled and sent back to the furnace and the finishing done in three passes; packs when finished are turned crosswise and carried on a cooling conveyor to two shears.

The tables are the Wean type and the doubler is the American Sheet & Tin Plate or Wean type, doubling the packs very hot. The sixes go back to the furnace as high as 800 degrees on the inside, because there is only a very short interval until they are doubled and on the way back at a speed of 300 ft. a minute. The fuel is coke-oven gas, very dirty and full of tar. We had quite a little bit of trouble with it, but that is being eliminated gradually. Their fuel consumption has been remarkably good, considering the size of the furnace, and that it is pushed to the limit.

I have here a telegram stating that for the week ending October 14th there had been made in 16 shifts 719 tons, an average of 44.94 tons per shift with total delays of 2 hours 46 minutes, exclusive of roll changing in the middle of the week. I had been told by one of my friends yesterday, when I showed him this telegram, that I must have blocked this out myself and had it sent to me. That is not the case.

The operation of the mill, as Mr. Wean pointed out, is done by natives. They have to have many spare men, compared to what we would need here. It is now becoming a roughing problem. Last week they averaged for the week 1123 pair finished per shift. That means two roughers at an average of 560 pairs per shift each, and that is about the limit in India, using 12 inch bars, 18½ and 20½ pounds per foot. I believe that is all I care to say, unless somebody wants to ask a question.

C. H. Verwohlt: I don't know that I have very many comments to make. We have four Wean Pack Furnaces and 3 Walking Beam Pair Furnaces working on raw producer gas. There are a lot of questions that we have in the operating end. We hear once in a while that we can't get uniformity, sometimes we wonder just what we can expect for uniformity. Our furnace is the single combustion chamber type, same as shown on Mr. Wean's illustration. We have tried different ways of operating with the bottom ports of the combustion chamber wall open, sometimes closed,—in order to get what the mill men say,—better uniformity on the pack. Sometimes, they say the bottoms don't warm up as well as the top. Personally, I don't see very much difference. You can't check it with the radiation pyrometer, but there is a real difference in operating on a mill, we know that. The packs sometimes go through showing that there is a lack of uniformity. Now just where that comes in, whether it is control of our gas or whether design in the furnace or what not, I can not say. I will say this control of producer gas on the furnaces is a real problem in order to follow the variation in load and the kind of material being heated. The furnace may be working at 1500 degrees for tight iron rolling, and the next order will come on for loose rolling. For this they want a temperature of 1200 degrees and they want it right away. They don't want to wait for it to cool down. It makes a real problem in handling the fuel; if you cut off the air and admit a surplus of producer gas, and, if there is enough temperature in the furnace, it will burn the producer gas and keep on going up due to infiltration of air and so on. This makes a problem that is pretty hard to meet.

F. E. Leahy: What is the length of your furnace?

C. H. Verwohlt: These furnaces are forty-five feet double row without center walls. If anybody has any information on controlling a furnace of this type, I would like to hear it. On the whole, the furnaces are working very nicely, the control is the same as on the majority of these furnaces. We aim to maintain a constant producer gas pressure at the burners, or rather in the pipe leading to the individual furnaces. We met that condition fairly well, but if anybody has any other information along the line of how they met the requirements of the operating end from uniformity of heating, not so much the across the pack, but from top to bottom we would be glad to hear it. They complain a little sometimes of having to change the spanner bar on the mill in going from breakdown to finished pack, but I don't think that is a very serious complaint. The lack of uniformity on the bottom and top sheet probably is the most serious complaint from the operating end, because we will get some pinchers once in a while.

The speed at which the furnaces are working can make another big problem. This is particularly true in going from tight iron to loose rolling. They slow up on loose rolling and it makes a very hard control problem.

R. J. Wean: The particular conditions under which the sheet mills have been operating in the last two years have changed the operating standpoint of sheet steel producers.

Up until a few years ago, steel companies segregated their sheet rolling capacity, building a full finished sheet mill in one building and operating it entirely separately from any sheet mill they might have which was producing electrical sheets or common black sheets for galvanizing. Frequently these mills would be built side by side but in separate buildings in order to keep the various classes of product separate.

Today, those conditions do not prevail. Operating departments must be prepared to handle various grades of sheet products on the same rolling unit regardless of whether the order is for ten tons of material or one hundred tons. They must be prepared to roll it when the order department releases it and on any one of their sheet mill units that is operating.

The condition Mr. Verwohlt has experienced is merely a variable demand proposition plus the fact that he has a rather short furnace, as furnaces are looked upon today. The heating in his furnace is far superior to anything received from old style furnaces but the crew is being educated to the point of expecting perfect heating. They have discovered that when operating at low rates they can obtain perfect heating with that particular sized furnace, and they want it just like that when they are operating at faster rates. While this is a normal expectancy in a furnace that has sufficient capacity, it should not be expected after they exceed the capacity of the furnace.

The finishing mills are up against this—If any bad roughing occurs on a separate roughing mill (which may be due to scaling or the inclusion of hydrogen if it is pickle finish) the roller on the finishing mill must take the packs as they come; if the results on his mill are not entirely satisfactory, even though his mill appears to be in good condition, he immediately concludes it must be poor heating because as far as the roller is concerned if his mill is in good condition and the material is coming from the furnace he of necessity must blame it onto the heating or otherwise take the blame for poor product.

As far as control of the fuel is concerned, I do not believe they are experiencing much trouble on automatic control where the center wall type of furnace is in use. The control for this type of furnace is much the same as for heavy oil which has worked in a satisfactory manner.

F. E. Leahy: There is one thought I had and that is we often assume that producer gas is always the same. That our producer operation is uniform —if we take an analysis of it the analysis will represent the gas and we think it being constantly made, but actually, our experience in the making of producer gas has justified us in going to automatic feeding of the coal. On a furnace heating other products than sheet products, we not only got increased production, but also better quality of heating due to the uniformity of the gas. Even on our present sheet and pack furnaces, two of which are Wean and two Surface Combustion Co., furnaces, we find that on these furnaces using a mixture of blast furnace and coke oven gas of an average of 350 B.T.U.'s it is necessary on certain rollings to enrich the mixture with natural gas to obtain production. Mr. Wean pointed out that the wide range in capacity required and temperatures necessary that unless you have some flexibility, it is difficult to meet them as quickly as desirable.

N. B. Ornitz: We had this problem put up to us by one of the local steel companies. In reference to uniformity of heating on a continuous furnace they wanted to increase the capacity at the same time. We therefore developed a high temperature circulating unit at very little cost. I have a report here with reference to what happened "Both units in No. 22 furnace have been beneficial in producing more uniform heating at fairly high rolling rates. We estimate that uniform heating could be obtained at ten percent higher rolling rates than without the units". The circulating unit consists of a fan installed in the top of the furnace, which increases the velocity of the gases passing over the material and permits more uniform heating throughout. In one plant, a difference in temperature between the top and bottom of a good sized furnace. (120" plate mill reheating furnace), was more than 350° F. After the installation the difference in temperature was less than 20 degrees.

H. V. Flagg: With respect to the comment on the limitations of producer gas as a fuel, I would say that if producer practice is properly developed, and the furnace application is made intelligently, a quite acceptable heating practice can be established. Automatic control of both temperature and atmosphere can be incorporated which will give satisfactory results. However, producer practice must be maintained at standards far beyond those ordinarily considered acceptable. Pressure must be maintained constant, the allowable fluctuation being not greater than plus or minus 0.05". W. G. Gas quality must

also be held constant which is possible only by the intelligent use of instruments showing fire conditions by skilled, conscientious workmen.

The short-comings mentioned by Mr. Verwohlt may have been caused partly by lack of fully organized producer practice and partly by a furnace capacity limitation. Because of lack of complete knowledge of mill capacities, there has been a tendency throughout the development of pack heating furnaces, to build furnaces with capacity inadequate for the demands of the mill. It has been necessary in such cases to operate the furnaces to the limit of their capacity and, as is always the case under such conditions, any small disturbance either in fuel supply or in continuity of mill operation, has had a disturbing effect on uniformity of heating.

I would like to ask Mr. Wean if he has found any satisfactory way of estimating furnace capacity in view of the wide variation in width, gauge, and length to be handled on an all purpose hot mill. In view of past experience, I am inclined to make the rather fantastic suggestion that it might be a good idea, if furnace limitation is to be completely eliminated, that the calculated length be doubled and about fifty feet added to that for good measure. To get back to the practical, most any length of furnace will do an acceptable job of heating if the operator is content to work within the limitations of that furnace.

F. Oppenheimer: I haven't got much to say about the Wean Furnaces. We have no Wean furnace in our plant but we have a furnace with the chain and flight mechanism in it. It is only about 40 feet long and we get very satisfactory results out of it. Our record, I think, in tonnage, has been about 45,000 lbs. in eight hours. We work 6 hour shifts but we reduce our tonnages to eight hour shifts for comparative records with other plants. We found a little trouble with bottom heating at times,—we don't use the radiant gap type of heating but we found we have limited our capacity to a slight extent by lack of sufficient bottom heating; however, that limit is very close to the limit of our mill. We have a hand mill and I doubt very much if our men could work much past the capacity of the furnace even if this were working on ideal conditions as the gentleman who just spoke said, "If you make your furnace long enough, you can increase your capacity, and if the steel stays in the furnace long enough, it will heat top and bottom."

F. E. Leahy: You mean if you increase your production, there is tendency to overheat the top of the pack which limits the capacity due to not being able to heat the bottom of the packs.

F. Oppenheimer: We can raise our control pyrometers, but this results in rash heating. There is a 350 degree heat differential between the furnace and the work. Another thing we found out in our 40 ft. furnace, in short packs, we seldom have trouble in heating doubled iron. The breakdown comes up and gets one pass, is doubled, and runs back into the furnace quickly. The doubled pack is only 40 inches long. There is only a small amount of steel coming out of that furnace in length, each time the roller presses the button. That means that each pack gets plenty of time to heat as there are a great many packs in the furnace. On one order of 26 gauge, 36" wide, I remember, we ran 960 pairs in 6 hours. That doesn't amount to our record tonnage, because, in heavier gauges, we sometimes run single iron using both sides of the furnace which has a center wall. There is very little trouble in controlling it. Our fuel consumption has been very good for that type of furnace, depending on the type of material. We made from 1600 cubic feet, per ton, up to 3,000 cubic feet. We found the furnace capable of heating 18 and 8 chrome-nickle alloy without any bad effect on the furnace, which speaks well for its construction.

F. E. Leahy: Does it affect the flux, at all?

F. Oppenheimer: No, we had the furnace well up over the control, so we don't know just what temperature we had. I judge we had at least 2,000 degrees in that furnace;—the work is slow, we weren't used to it, but it was an interesting experiment. Our flights weren't damaged to any extent. We are very well satisfied with our installation.

F. E. Leahy: If I understand the sketch correctly, Mr. Wean, I notice that you fire towards the doors, in place of all in one direction.

R. J. Wean: That is correct.

F. E. Leahy: What is the advantage of that and what do you gain?

R. J. Wean: We take hot gases in through the radiant gap, instead of pulling cold air into the door. The result is, that it gains the equivalent of about three or four feet on your charging end, also it is somewhat easier to control. I have a way of gauging capacity, and that is, a ton per hour for every ten foot of length of the furnace. That is to take an average condition on your product. But I found out from practice on short single line furnaces and double, without the center wall, and with center wall, that a ton per hour of every ten foot of length for each chamber, if it is a double chamber is a good rating for a furnace. This point of high temperature on a furnace having been raised by Mr. Oppenheimer, I want to relate something I just learned today: About three years ago, we put a furnace at Woods Works, American Sheet and Tin Plate Company and what was then their full-finished sheet mill. Since that time they practically have abandoned the rolling of full-finished sheets at that plant, and that part of the mill has been idle, and another rolling unit in a separate building has been used for the production of stainless steel, so they made a normalizing furnace for stainless steel out of a pack furnace. They are actually normalizing, or annealing, as they call it, stainless steel sheets. It is a chain-type furnace, with the fingers, and I know the product has to be heated around 1860 degrees, so that they must have higher furnace temperatures than that and they are doing it all the time. It is regular practice. I know another mill that should have bought a normalizing furnace several years ago, but instead bought a pair and pack furnace. They shut down on Friday at six o'clock on the pack and pair furnace, and then over the week-end, they normalize, and they have been doing that for over a year.

F. E. Leahy: There isn't any answer to bottom heating?

R. J. Wean: Bottom heating may be all right but top heating is too hot and would give the impression of cold bottoms. This is brought about by furnaces being pushed beyond their normal ca-

pacity. Higher temperatures in the furnace is the only way to obtain increased capacity from a furnace when the tonnage required is in excess of the comfortable capacity of the furnace; that is, higher temperatures raise the temperature of the top sheet so that it is in excess of the rolling temperature desired while the bottom of the pack may be exactly the temperature desired for rolling, giving an impression of cold bottoms while in reality it is merely lack of uniformity. This lack of uniformity is not present when operating within the capacity of the furnace.

G. J. Hagan: In defense of manufacturers and designers of heating furnaces, especially after the remark that "any furnace say of 50 feet in length should be made 100 feet, and then doubled in length to give the desired capacity and uniform heating" I certainly take exception.

The rule is quite simple to make set up for given requirements to design any furnace of this type. The operators when making inquiry, make their own set ups for tonnage desired, and other conditions, but as soon as their mill is broken in and crews become fully acquainted with mill and furnace, it is common to exceed the original tonnage expectations, the furnace being pushed to deliver excess tonnage, the heating quality naturally is not what it should be. The furnace job when first ordered is bought in competition, so usually the furnace manufacturer designs the furnace to meet the set up of original specifications, and much excess tonnage from his furnace can not be expected.

A furnace whether underfired, overfired, or both will heat uniformly when time cycle is correct, but when overfired alone, and the furnace hearth not of sufficient volume for good heat storage, the bottom of packs will not be properly heated, even with a correct furnace design for uniform heating, if the operator speeds up the furnace beyond the original intent the packs will be delivered either with cold bottoms or cold tops, and this should not be blamed on the furnace.

R. J. Wean: Just in connection with that, I don't know how many of you were at Allegheny Steel yesterday, October 18, but those furnaces represent what we think is a comfortable length. They are 60 feet long, center wall, 2 chamber furnaces and I have yet to hear of this lack of uniformity and it is all because the capacity is there and they don't have to push it beyond that point.

T. B. Bechtel: What we have heard here regarding heating troubles with these furnaces points definitely to one major cause of the difficulties. This is that the furnaces are oftentimes and necessarily run with a considerable temperature gradient or heat head above the temperature to which it is really desired to heat the steel.

Insufficient hearth area for the required production is, of course, the underlying reason for this practice. For this class of heating, trouble free operation may only be accomplished through the installation of sufficient heating area for the tonnage requirements. This will permit of operation close to the temperature to which it is actually desired to heat the stock, and not several hundred degrees over that figure.

F. E. Leahy: In the construction of these furnaces everyone knows that the alloys play an important part and it has been rather remarkable the way the alloy manufacturers have been able to meet the demands placed on them. They take a furnace designed to work 1600° F. maximum and operate it at 2000° F. We have a representative of the Driver-Harris Company that might tell us some of the furnace problem of his side.

W. E. Blythe: We have no difficulty in designing alloy castings to operate up to 2000 degrees F. It is entirely a matter of experience in correct design, and if we know the desired operating temperature, the necessary loading and what fuel is to be used, the problem is readily solved.

A. I. & S. E. E.

PITTSBURGH SECTION MEETING

J. W. BATES, Chairman — J. I. KASPARI, Secretary

Cardinal Room — William Penn Hotel

2:30 P. M.

Saturday Afternoon, FEBRUARY 24, 1934

"MAGNETIC INSPECTION FROM THE BILLET TO THE FINISHED PRODUCT" by Dr. Sigfrid Specht, Chief Engineer, Ferrous Magnetic Corp., New York, N. Y. and to be presented by his associate Mr. R. T. Rohrer.

Outline of the paper—Non-Destructive Inspection of Grain Size —Hardness — Carbon Content — Strain Stresses — Carbide Segregations—Inclusions in Steel from the Billet to the Finished Product.

Dr. Specht says:

Magnetic Inspection is non-destructive. In the case of steel production, it can be applied far back in the process to give facts and not opinions of existing conditions in the manufacturing process. The facts revealed will lead to constructive and corrective methods. It will locate responsibility. Magnetic Inspection, sharpens, and controls the practice, therefore automatically improves the quality of the product. The speed of inspection is so rapid that it is economical to test each and every piece produced. The user or purchaser of steel can also check his product for the particular properties that apply to the use to which he puts his finished product. No needless machining, forging, and other expense is expended on undesirable products. The heat treatment can be checked, even while the steel is moving; the defects located; the strain determined; the decarbonization indicated and measured.

Recent Developments In Design and Operation of Industrial Furnaces

By G. A. MERKT,
Manager, Combustion Control Dept., Morgan Construction Co., Worcester, Mass.

Presented before Combustion Engineering Division of the A. I. & S. E. E. at the Twenty-ninth Convention in Pittsburgh, October 19, 1933.

G. A. MERKT

Management, in charge of vast industrial equipment and processes and principally concerned with the profitable production of goods, may broadly define the ideal operation of a furnace to have utmost fuel economy with whatever fuel may be available and to produce correct treatment of the furnace charge. Operators and engineers have struggled with these requirements throughout the long years of experimentation and development upon which the present status of furnace construction and operation rests. A more technical interpretation of the above broad definition of requirement would be a furnace system suitable for the most advantageous transfer of the heat in the fuel to the product. This heat transfer must be as rapid as possible and must not be injurious to the work. Thus, the problem has always been one of combustion combined with the task of utilizing the heat developed.

Particular attention has been given to the importance of getting the air of combustion in contact with the fuel as thoroughly and quickly as possible and of directing the products of combustion upon the hearth. Thus in melting furnaces, such as the open hearth, the aim has been to give a certain amount of direction to the flame and endeavors in this connection are prominent in furnace design. The "venturi port" of the conventional open hearth furnace well represents this endeavor to direct the flame towards the hearth by carefully chosen gas port location and by converging air port delineation. The latter is principally relied upon to give the desired effect. Other examples of this endeavor are represented by the Moll furnace and the Terni furnace in which high gas velocity through long gas ports are intended to induce combustion air in the proper direction across the hearth. The combustion in these furnaces proceeds with a predominately luminous flame and the heat transfer from the products of combustion to the bath is principally by radiation. The velocity with which the flame may impinge upon the hearth and thereby the heat transfer by convection, is somewhat limited by the fact that the ingoing and outgoing ports are alike in area, and while they must be chosen large enough to permit evacuation of the furnace chamber by the gases of combustion they are not small enough to sufficiently increase the velocity on the ingoing side for strong impingement. A more intensified flame direction is produced in constructions where the port area is reduced on the ingoing side while the outgoing furnace gases are carried off through wide open ports. A striking example of this type of construction is the McKune furnace. With this provision for high velocities and sharp flame direction, heat transfer by convection increases considerably and a combustion process may be used in which the ensuing flame is the product of turbulent combustion and may be non-luminous or semi-luminous such as in the use of coke oven gas or natural gas. A still more radical method of intensifying flame direction and heat transfer by convection is a method of "Target Firing", an arrangement by Billiar, in which the fuel is introduced from the roof of the furnace through one or more burners and the air and waste gas only are reversed. If one may judge by the statistical record of installations made of the various types of furnace arrangement, the practical value of these well founded endeavors over and above the results obtained in the conventional type of furnace, is not of sufficient magnitude to offset certain difficulties which present themselves in construction and operation.

The control of the combustion process in all furnaces depends for its maximum effect upon regulation by natural draft and furnace pull or by mechanical draft and forced air (balanced draft). The latter, which has greater flexibility, a wider range of capacity, and a more definite character as to functioning is chiefly to be found in connection with waste heat boiler installations as auxiliaries to the furnace. A more recent development utilizing balanced draft independent of waste heat boiler auxiliaries and at the same time considerably extending the

regenerative capacity of the furnace is the Isley Furnace System. A number of installations here and abroad have demonstrated the value of definite regulation which may be adjusted automatically or very conveniently by hand. While most furnaces utilized for melting purposes can be conveniently and economically fired with any of the available fuels, there are nevertheless some difficulties experienced in the use of rich fuels, such as coke oven gas and natural gas, and this difficulty seems to have its origin in the character of the flames produced.

More pronounced is the difficulty experienced with the combustion of certain fuels in the heating furnaces and process ovens which are required to operate at a lower working temperature than that of melting furnaces. A few of them are regenerative, more often they are fired in one direction only and waste heat recovery is usually obtained by recuperation. In these lower temperature furnaces, the productive capacity of the furnace system is not limited so much by the possible rate of combustion, but rather by a comparatively low rate of heat transfer from the products of combustion to the work or charge of the furnace. A perfectly balanced rate of combustion to suit the rate of possible heat transfer to the work has sometimes been called "the thermal equilibrium" of the furnace system. In addition, the conditions of combustion are dictated by the heating process and are bounded by limited maximum temperature and a definite furnace atmosphere. These boundaries are usually obtainable with fuels of moderate heat value per unit volume. When fuels of high heat value are used, it is necessary to moderate the furnace gas temperature either by firing through a Dutch oven, absorbing the excess temperature in brickwork and dissipating a portion of it, or by diluting the high temperature combustion products with excess air where the presence of oxygen in the furnace atmosphere is not objectionable, or by incomplete combustion effected with insufficient combustion air, or by other more economic methods of adjusting the conditions of combustion, later discussed.

The more or less visible sign of combustion is the flame, which is distinguished from the products of combustion in that the latter lie outside of the boundary of complete combustion so that it may be said that a flame consists of a body of gradually combining elements of combustibles intermixed with combustion products. The most important property of the flame is its emissivity, that is, its heat radiating quality which is to some degree indicated by the luminosity of the flame. Another important property of the flame is its temperature and the latter varies in its potential inversely with the duration of the combustion process. Experiments with powdered coal indicate that a flame produced with a combustion speed of 1/10 second is between 1100° and 1200° F. hotter than a flame produced with a combustion speed of one second, the boundary points of complete combustion lying along a curve with reference to the duration of combustion (see figure 1). The duration of the process is also analogous to the length of the flame from which follows that as the combustion process is being delayed the length of the flame is being increased. The emissivity or coefficient of radiation of the flame, on the other hand, is a maximum at the beginning of combustion and falls off at the point of highest flame temperature reached, being a minimum at the boundary of complete combustion, that is at the end of the length of the flame. Therefore, the longer complete combustion can be delayed over a given path the greater is the average coefficient of radiation over the total path. It is the opinion of many investigators that the heat transmission from the flame and from the products of combustion to the hearth is effected mostly by radiation, although convection and heat transfer by convection are always present. Keeping the foregoing in mind it may well be recognized that the productive capacity of the furnace will reach its maximum when the conditions of combustion are so regulated that in the process of combustion the flame extends over the greater part of the hearth. As we have pointed out before, the speed of combustion or flame propagation may be lowered by burning the fuel with a deficiency of combustion

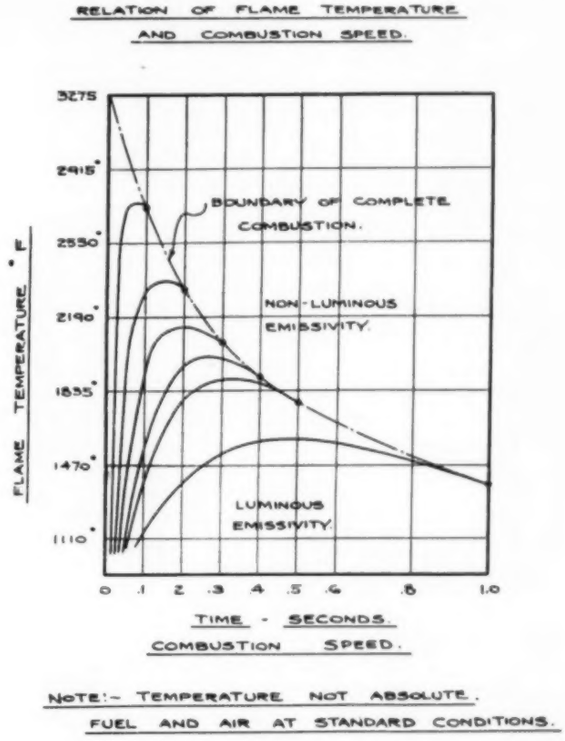


FIG. 1

air. This, however, results in a waste of unburned fuel and presents other undesirable features such as smoke, soot, carbon monoxide gas, etc.

More efficient means of bringing about the much desired "delayed" combustion are "diffusion firing" and "recirculation". In "diffusion firing" the mixing of fuel and combustion air or rather the rate at which they can get together is gradual and therefore relatively slow. Fuel and air in separate streams and from separate ports are being catapulted across the hearth in parallel motion of their respective masses. Turbulence in each of the two streams causes boundary friction between them which extends over the entire length of the projected stream. This, together with the natural tendency of two gases to intermingle or diffuse, brings about a gradient mixing. The luminous flame and radiating qualities which are thus created are well known. Many applications of

this method of firing have been made in heating furnaces of comparatively low rate of heat transfer. Another method of slowing down combustion, or of retarding the development of the flame, is to be found in the use of recirculating furnace gases which dilute the flame body after partial primary combustion, bringing about a lowering of flame temperature and a more or less incandescent glow of the entire furnace atmosphere. As in the case of diffusion firing the slightly lower flame temperature is offset by its greater emissivity and (in the case of recirculation) by the production of a much larger flame volume which, in turn, increases the convection in the furnace and thereby the heat transfer due to convection. Since recirculation returns a portion of the sensible heat in the furnace gases it improves fuel economy. The greater content of inert gases in the flame body serves to protect the work, not only against destructive temperature, but also against destructive furnace atmosphere in the form of free oxygen since, with the same amount of excess air as in straight combustion, the relative free oxygen content is considerably less with recirculation. This method of conditioning the combustion process to suit the requirements of the furnace has a wide range of application, particularly in any arrangement in which the degree or rate of recirculation can be regulated in an organized manner.

If we now examine the flame temperature produced by various fuels under perfect combustion (turbulent combustion) we find that the richer fuels, that is fuels with a high heat value per unit weight, produce a more elevated flame temperature, while the leaner fuels have flame temperatures of more moderate potential. It is generally conceded that the leaner fuels, such as producer gas and blast furnace gas, are the most ideal and fool-proof fuels for heating operation. Most excellent results have been obtained in Isley soaking pit furnaces fired with 100% cold blast furnace gas. A similar installation in a large forge furnace gives highly satisfactory results when heating a 100-ton ingot with cold blast furnace gas. This experience suggests the idea of reducing the richer fuels to the level of the leaner ones by admixture of inert gases.

It has been reliably established that a combustible mixture of fuel, air and inert gases containing an energy of 30 B.T.U's. per cu. ft. standard condition will support combustion. This is a considerably lower content in the mixture than will be found in the theoretical combustion of either producer gas or blast furnace gas. It should therefore be perfectly safe to reduce the richer fuels to the condition of producer gas, which would allow an admixture of inert gases to the combustible mixture of gas and air, of about 27% in the case of natural gas, about 39% for coke oven gas, about 32½% for illuminating gas and about 35% for carbureted water gas (see table 1). If we reduce the combustion condition to that of blast furnace gas, we can add in the case of natural gas 62½%, for coke oven gas 67%, for illuminating gas 63%, for carbureted water gas 62% and for producer gas 20%. The lowest limit of heat content per cubic foot of combustible mixture under standard conditions would permit of an admixture of 180% for natural gas, 280% for coke oven gas,

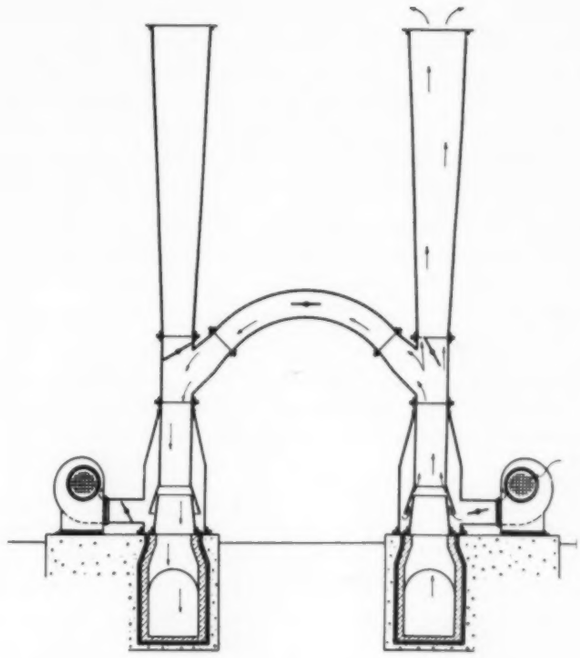
TABLE I—HEAT CONTENT IN COMBUSTIBLE MIXTURES

		Natural Gas	Coke Oven Gas	Illuminating Gas	Carbur. Water Gas	Producer Gas	Blast Furnace Gas
A	Heat Value per cu. ft. (std. cond.) B.T.U.	1000	480	550	510	145	92
	Theoretical Air of Combustion cu. ft.	10.92	4.19	5.14	4.69	1.195	.67
	Combustible Mixture (std. cond.) cu. ft.	11.92	5.19	6.14	5.69	2.195	1.67
	Heat content per cu. ft. comb. mixture B.T.U	84.5	92.5	91.0	89.5	66.0	55.0
B	Inert Gases added to make the Heat content in combustible Mixture equivalent to that of Producer Gas Combustion.						
	Inerts added cu. ft.	3.26	2.06	2.16	2.01		
	Total Combustible Mixture cu. ft.	15.18	7.25	8.3	7.7		
	% of Theoretical Combustible Mixture	127	139	132½	135		
C	Inert Gases added to make the Heat content in Combustible Mixture equivalent to that of Blast Furnace Gas Combustion.						
	Inerts added cu. ft.	6.28	3.51	3.86	3.56	.435	
	Total Combustible Mixture cu. ft.	18.2	8.7	10.0	9.25	2.63	
	% of Theoretical Combustible mixture	152½	167	163	162	120	
D	Inert Gases added to make the Heat content in Combustible Mixture 30 B.T.U's per cu. ft.						
	Inerts added cu. ft.	21.38	10.81	12.16	11.31	2.64	1.39
	Total Combustible Mixture cu. ft.	33.3	16.0	18.3	17.0	4.83	3.06
	% of Theoretical Combustible Mixture	280	308	297	300	220	182

197% for illuminating gas, 200% for carbureted water gas, 120% for producer gas and 82% for blast furnace gas. Considering now a furnace in which a large amount of the sensible heat in the waste gases is returned to the combustible mixture, either by recuperation or by recirculation, then the theoretical limit of admixture of inert gases will be somewhat wider than that cited above, so that it is reasonable to expect the availability of a considerable range within which the combustion of rich fuels can be conditioned to suit the character of the furnace and the work which it is required to do.

The foregoing considerations are made use of in the Morgan Combustion Conditioning System which is in virtue a novel arrangement of recirculation. It differs, however, from the conventional system of recirculation in that dilution by furnace gases is directed to the combustion air rather than to the fuel or flame body. In the case of regenerative furnaces (figure 2) the apparatus consists of a pair of ejector tubes, one for each end of the furnace system, each tube served by low pressure high volume air and the throats of the two ejector tubes connected by a bridge flue. The waste gases drafted from the flues by the ejector tube are thoroughly mixed with the ejector air while passing through the throat under turbulent flow. By simply manipulating suitable dampers to their proper adjustment any desired portion of this throat mixture may be returned from the outgoing ejector tube to the ingoing tube and from there through the flues and checkers to the furnace ports. The precise laws which govern the ejector principle make it possible to so proportion the ejector nozzle and throat that the portion of the throat mixture which is being returned to the furnace will contain the required amount of combustion air. It is, however, more practical to design the ejector for a leaner air mixture and to make up the balance of combustion air required with fresh air from the supply to the ingoing ejector tube. Thus, a certain amount of the waste heat ordinarily discharged to the atmosphere is being returned to the system in a most effective manner. The temperature of the waste gases at the base of the stack is usually so low that further recovery by either regeneration or recuperation would be very inefficient, whereas by this direct mixture of atmospheric air with the gases practically no losses are occurred in the process of heat recovery. The total waste heat discharged through the ejector tubes to the atmosphere is, however, always equivalent to the sensible heat contained in the least combustion product which corresponds to the amount of fuel used. Under ordinary conditions when excess quantities of waste gas arrive at the base of the stack due to infiltration of air or due to excess air, the regenerative system becomes less efficient in proportion to this excess air, particularly if due to infiltration. In the recirculatory system here discussed this is not the case, because for the larger weight of furnace gas feeding the checker system a correspondingly larger weight of combustion atmosphere returns; if anything, the efficiency is greater due to more rapid convection in the checker passages, the only limitation being one of resistance to flow which, however, is not as narrow as the limitation in this respect when depending upon natural draft.

The Isley Furnace System in connection with the



ISLEY FURNACE SYSTEM WITH COMBUSTION CONDITIONING DEVICE

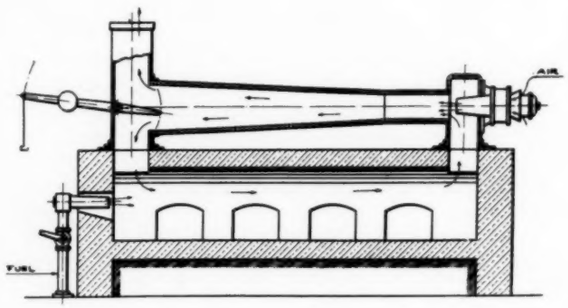
FIG. 2

Morgan Combustion Conditioning Device lends itself to the correction of difficulties which are experienced in large furnaces when light gases, such as natural gas and coke oven gas are used as fuel. In the conventional type of construction sufficiently high air velocities may be obtained to cause very sharp combustion and fairly good flame direction to the charge in the hearth, so that at the beginning of the heat when cold scrap with comparatively very large surface exposure and high heat conductivity and specific heat property furnishes a target for the short but extremely hot and practically non-luminous flame, satisfactory heat transfer is the result. As the charge is melted and covered with slag, which in itself is an insulator against heat it becomes desirable to lengthen the flame without, however, much increase of fuel. Simultaneously, the furnace chamber has become much larger as to available combustion space and the light but very rich fuel is permitted to assume any possible combustion due to space accommodations and then float away leisurely towards the exit with a natural tendency to rise to the roof towards the outgoing end. As the heat progresses and exothermic reactions raise the temperature of the bath, less and less fuel must be used so that the original ingoing port and the combustion space over the bath become altogether too liberal for proper control of the condition of combustion and of the direction taken by the combustion products. Under these circumstances it is easily possible to experience a combination of excess furnace temperature, low emissivity and inadequate convection so that in spite of damage to the refractory materials it becomes difficult to finish the heat. The Morgan Combustion Conditioning System, Figure 3, offers a remedy for the detrimental combination above cited. By making use of the provisions incorporated in the

apparatus it suggested that during the melting down period pure air without recirculation be used in the usual manner, and that more and more recirculation be used as the heat progresses and the slag line becomes level. The recirculated preheated furnace gases will not only fill the voids which are created by an abnormally large combustion space, but as has been pointed out earlier, will condition the combustion of an unruly fuel to produce a more suitable flame body.

By far the greater use of combustion conditioning suggests itself in connection with a multitude of heating furnaces and process ovens in which very often the permissible working temperature is decidedly limited and in many cases lies below the flame temperature of even the leaner fuels. There are literally thousands of heating processes in which the major portion of the heat developed by the combustibles must be dissipated one way or another because the product will not endure such temperatures. There is quite a number of processes in the steel industry, particularly in the finishing departments, which comes under the realm of the above limitations. In addition to this there is a predominant demand for a furnace atmosphere which is suitable for the process and often calls for a low free oxygen content in the furnace gases. In direct opposition to these requirements is the ever growing use of rich gaseous and liquid fuels which are convenient to handle, such as natural gas and the by-products of the coke and oil industries, fuels which are particularly attractive to the operator of small equipment and intermittent processes. The arrangement of the Morgan Conditioning System in connection with heating furnaces and small industrial ovens is capable of many variations to suit the physical shape and space presented by the problem. In the case of larger furnaces, it may consist of an ejector tube similar to those used in the Isley Furnace System with a branch connection from the throat to the firing end of the furnace either through recuperators or direct. In smaller furnaces or in furnaces which are side-fired through a number of burners, small ejector units may be placed across the roof of the furnace, or underneath, returning the products of combustion to the burners and discharging the unused portion to the atmosphere. Air blowers either driven with variable speed motors or regulated by dampers furnish a ready means for the adjustment of the furnace pressure and rate of recirculation in proportion to the amount of flue gas which is to be returned to the combustion chamber. In each particular furnace with a definite furnace process and a given fuel, a certain rate of recirculation will be found to be the most practical, so that readjustment of the throat damper will not become necessary when this rate of recirculation has been established. It will then be merely a matter of regulating fuel and air supply to suit the capacity of the process for the production desired.

The equipment can easily be added to existing furnaces, in most cases without any major changes of the furnace proper. The fuel economy which is to be expected by this system of conditioning the combustion of a high power fuel to a delicate process, provides an economic attraction which is further enhanced by simplicity of construction in new furnace installations, particularly of large units. In large steel heating furnaces of the continuous type in which the cold charge cools the furnace gases before they leave the furnace to an extent where heat recovery becomes an expensive investment and where the use of rich fuels under straight combustion creates excessive localized heat with rapidly falling emissivity a short distance from the port, the system as described offers not only a correction of this unsatisfactory situation but also the possibility of a furnace construction which eliminates special heat recovery apparatus with its complicated and expensive underground construction.



MORGAN COMBUSTION CONDITIONING SYSTEM

FIG. 3

In conclusion, it may be stated that the recirculation of approximately 30% of the waste gases in a glass melting furnace, fired with natural gas, has given highly satisfactory results. In the instance here cited the waste gas was returned to the port without regeneration by tapping the flue to the stack. As may be readily understood, the regenerators in this case are heavily overloaded on the outgoing side and are necessarily incapable of returning their stored up heat with reasonable completeness owing to the fact that the air required for combustion is no more in connection with recirculation than it is without it. As pointed out earlier in this discussion, the balance of heat exchange in the regenerative system remains the same in the Morgan Combustion Conditioning System because both the recirculated furnace gases and the combustion air return through the regenerators to the furnace.

Discussion

Discussion Presented by

C. L. Joly, Vice President, Smoot Engineering Corporation, Pittsburgh, Pa.

M. J. Conway, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

Feodore F. Foss, Assistant to Chairman and General Metallurgist, Wheeling Steel Corporation, Wheeling, W. Va.

G. A. Merkt, Manager, Combustion Control Dept., Morgan Construction Company, Worcester, Mass.

C. L. Joly: We have a great many furnaces under control, and we have found that the furnace pressure regulator which we install on open hearth furnaces, permits the operator to increase the time of contact of the gases with the bath, by maintaining a pressure on the furnace instead of a suction, during all phases of heat input.

The increased efficiency of many furnaces, after the installation of furnace pressure control, is due to the fact that, the regulator maintains the furnace full of burning gases regardless of the area of the furnace or the amount of fuel admitted to the furnace, and prevents the infiltration of raw air through the doors and cracks. During the melting period of the heat we, with proper operation, consume almost twice as much fuel as we do during the refining or working period of the heat. No furnace can be so designed as to obtain a uniform pressure within itself, owing to the fact that during the period when we are using the larger amount of fuel, the area of the furnace is smallest as the scrap by its bulk takes up considerable space, and that when we are admitting the smaller amount of fuel we have the full furnace area, as the charge is melted down.

The work required of a furnace pressure regulator is rather difficult, and requires a regulator which is very fast, very sensitive, accurate and stable, and it must be engineered to fit the particular application. The regulator must react to changes in furnace pressure of less than half of one hundredth of an inch of water column pressure. From our experience in the installation of and operation of control on over fifty open hearth furnaces we are led to believe that we are doing this. There is no meter in operation which is sensitive enough to measure these pressures, but we are working on a meter which we believe will record these pressures accurately and without a doubt.

Various users of open hearth control equipment claim that the furnace pressure regulator is responsible for at least 60% of the increased efficiency of the furnaces. In as much as I have operated all but two or three of our controlled furnaces, I would judge, from my own observation, that this statement is true, and I believe that, as Mr. Buell claims, this is due to the increased time of contact of the gases with the bath. A difference of .01" water in pressure in the furnace makes a difference of 200 deg. F. on the checker temperatures, and 25% in the steam generation in the waste heat boiler for a furnace tapping 115 tons, (single pass checkers, water tube boiler, producer gas fired, 420#/gross ton fuel rate.)

Most of our success in the control of open hearth and other furnaces, is due to the fact that we have stayed with the equipment and worked out the problems as they have arisen. You cannot possibly stick the control equipment on the furnace and leave it to the operators to make it go. It is my belief that, until the control performs, and until everything possible has been done to make it acceptable to the operators, it is the duty of the manufacturer, provided he gets the proper collaboration from the management and personnel of the plant, to stay with it.

Each furnace has its own idiosyncracies, which must be studied and met. With proper control equipment we can meet any condition which you may desire on the furnace, and we can maintain these conditions indefinitely, within the limitations of the auxiliary equipment.

You may have ideas for the operation of the furnace with which we do not agree, and we may have some with which you do not agree, it is our business to show you wherein our ideas are better, or to carry out your ideas. This can only be done, if the control manufacturer understands your problem thoroughly.

If we work with you, and stay with you, then we are bound to succeed. Neither one of us should try to dictate to the other, we should by all means collaborate.

M. J. Conway: Mr. Merkt has given us another angle to consider in the efficient utilization of fuel in the open hearth process, that of the greatest possible use of heat transfer by convection and the development of the type of combustion which produces the luminosity required to aid heat transfer by convection.

It seems to me that the theory of effectively controlled draft, or regulation of contact time of gases is very essential to obtaining the greatest heat transfer by convection.

No doubt the port of an open hearth furnace as at present designed is a poorly proportioned burner or mixing device, and as such, is likely to change its dimensions during a run of very few heats due to abrasion, erosion, and other causes. Therefore, the furnace operator uses the fuel valve to give him the desired flame length usually at the expense of excess fuel and shorter furnace life. If this same effect can be produced by the use of recirculated gases as described by Mr. Merkt, so long as sufficient fuel is being fed to the furnace to maintain the desired temperature differential, then the system so ably described has possibilities we cannot afford to ignore.

Feodore F. Foss: In the paper "On recent developments in design and operation of industrial furnaces," Mr. G. A. Merkt has endeavored to cover so much ground, that, quite naturally, he has touched many important subjects only very slightly.

Several furnaces' construction, different kinds of fuels and their importance for different purposes have been mentioned, the temperature of combustion, con-

stitution of flame and its radiation have been discussed, diffusion and other phenomena of combustion have been compared—all that as an introduction to the main problem of his presentation—namely, that of recirculation of combustion products.

This variety of subjects compels me to confine my remarks only to the most salient points of the paper.

When "design and operation of industrial furnaces" is made as a principal theme of a presentation, we, naturally, expect to see in the text a statement as to which principal group of the furnaces in the long list of industrial heating equipment the reference is made. We expect to know temperature ranges and the character of furnace regime which are considered by the author. Open hearth, glass melting, billet heating furnaces, furnaces for carburization of machine parts and drying kilns all belong to the industrial furnaces, but the characteristics of their work are so different, that no general formula for their design or general recommendations for their operation can be given, except, possibly, that all such furnaces should be constructed and managed efficiently and give products of good quality. It is clear, that combustion principles, which can be applied to one group of furnaces, are completely inapplicable to another. This lack of concreteness in Mr. Merkt's paper makes deductions from it rather vague.

In the beginning, Mr. Merkt states the following: "Management in charge of vast industrial equipment and processes, and principally concerned with the profitable production of goods may broadly define the **ideal operation** of furnace to have the utmost fuel **economy** with whatever fuel may be available and to produce correct **treatment** of the furnace charge." This statement, in which the two important characteristics of the ideal operation are underscored by me, does not cover the third not less important item and that is, of the **initial cost** of the equipment and of its maintenance. This item of initial cost, having great influence in every engineering proposition, becomes loaded with unusual importance when expenses are made in an attempt to achieve higher degrees of efficiency of a combustion process by utilization of waste products.

This third characteristic, which, in many cases, is overlooked and very often is not considered with the seriousness it deserves, has been left completely out of Mr. Merkt's presentation.

Speaking further on what the author calls "thermal equilibrium" or, in other words, on the rate of combustion of different (of high and low heating value) fuels for different furnace regimes, the author states, "that in the lower temperature furnaces, the productive capacity of the furnace system is not limited so much by the possible rate of combustion, but rather by a comparatively low rate of heat transfer—from the products of combustion to the work or charge of the furnace."

My understanding of the combustion leads me to believe, that such general statement does not interpret combustion phenomena in a low temperature furnace with complete correctness. It seems to me, that the thermal and chemical regime of such furnaces **does** actually depend on the combustion phenomena combined with the mode of gas and air preheating. This can be stated even more strongly—that the heat transfer in every furnace is in a direct dependence of combustion conditions.

When a combustion engineer has several kinds of fuel available, he, natuarlly, selects the most suitable fuel for the purpose, because such fuel in normal conditions will give the desired results without any special arrangement of the equipment. Otherwise, it is only a matter of combustion method which he will apply to make every fuel give him the desired temperatures and desired heat transfer.

At this point, it is interesting to note, that the author, in talking on flame temperature produced by various fuels under perfect combustion, says, that "fuels with high heat value per unit weight produce a more elevated temperature, while leaner fuels have flame temperatures of more moderate potential."

Such interpretation of combustion temperatures is theoretically correct and is frequently used without any reference to the temperature of air pre-heating. It cannot be accepted, however, by a combustion engineer as a basis for new furnace development, unless, of course, the expression "moderate potential" has a special numerical meaning. Lean fuels known to the fuel technology, if burnt properly (that means if gas and air are pre-heated to the necessary degree), will give the necessary elevated temperatures required in metallurgical practice. For example—blast furnace gas of 92 B.T.U. burnt in the air, pre-heated to 2000° F., will give flame temperature of 3175° F. in ideal mixture. When such fuels are used, however, it is not the temperatures of flame which have to be considered, but the furnace capacity and efficiency of production.

In a further example of successful application of blast furnace gas to soaking pits and forge furnaces, the author finds "the idea of reducing the richer fuels to the level of leaner ones by admixture of inert gases." This seems to be based on erroneous interpretation of the role played by inert gases in the furnace heating space. The difference in the effect of blast furnace gas and, for example, of coke oven gas combustion, lies not in the degree in which inert gases are present in both gases, but in different combustion conditions of two different systems of fuel (C—H—O and C—H) and, of course, on different modes of heat transfer and different composition of gas products created by two different types of combustion.

The combustion of pre-heated gas and subsequent heat transfer from them depends, primarily, on the following: Migration of fuel and air molecules, preparation of fuel for ignition, as a function of previous phenomenon, speed of ignition, velocity of gases and products of combustion. The two mentioned systems of fuels (that is, blast furnace and coke oven gas) have those phenomena occurring quite differently and there is a basic difference in the way, by which water gas (that is, combination of CO and H_2) is created from both of these fuel systems.

Incandescent carbon, which plays such an important role as a radiation medium and as a catalyst, originates in both systems at different temperatures and conditions.

In accordance with my remark on the initial costs of every heating device, it is appropriate to mention here, that the cost of construction and operation of furnaces for leaner fuels, referred to a unit of product and time, is always higher than that of

furnaces designed for more concentrated fuels. Only the low price of such lean gas (actually by-product) permits its profitable utilization and construction of such complicated and expensive furnaces, as for example, heating furnaces with "split" flame.

When we compare the influence of combustion condition, enumerated above, with the role inert gases play in heat transfer, we see, that this role is quite insignificant in the series of conditions governing the combustion and heat transfer when lean gases are burnt. On the other hand, inert gases, being heated to the furnace temperature, considerably increase the volume of combustion products, and noticeably affect the heat balance of the furnace by returning less than taken away.

The fuel technology, up to the present time, strove to produce gas fuels with concentrated heating value and the idea of dilution of rich gas by admixture of inert gases is a distinct step backwards. It may be stated even, that a fuel of blast furnace gas composition would not be used at all if it had to be produced "per se" and not received as a by-product.

Coming now to the recirculation problem featured in the paper, we see, that the author connects "diffusion firing" with "recirculation" for the purpose of bringing about a "delayed combustion."

To my mind, this connection hardly can be made, as both of these phenomena can be compared only antithetically. The diffusion combustion has as its first condition, the division of gases to smallest streams, to facilitate the migration of fuel and air molecules to the highest possible degree. If there is any "delay" in the gas fuel diffusion phenomena, it is, when gas and air, after passing through a catalyzer (and every diffusion burner should be considered as acting catalytically), are burned in conditions of constant volume and not in conditions of constant pressure. That means, that the velocities of gas and air exactly before burning have been practically nil. The velocities of actual combustion, however, in a diffusion burner, are great and by no means is the **combustion delayed.** Quite to the contrary! Combustion conditions of gases diluted with products of combustion containing inert gases will be—ceteris paribus—sluggish, as the molecules of fuel will be separated from air molecules by thick layers of non-combustibles—inert gases and products of combustion.

The principles of flame propagation and influence of slow velocities' flame on the furnace regime have been discussed by me somewhere in this issue and I will avoid here a repetition.

The idea of combustion products' recirculation is not new. Already, in about 1880, Friedrich Siemens had applied blast furnace gases for circulation in gas producers for the purpose of regulating the gas producers' temperatures by endothermic reactions.

Ferdinand Fisher, in 1890, has shown, that such method was **uneconomical, because cyclical movement of large quantities of nitrogen took away** too much heat from the gas producer.

In 1912 an attempt of using waste gases for regulating the gas producers' operation was again made on a large scale for heating city gas retorts by Eldered Process Company. The application of this process was, quite naturally, short-lived.

At this time I have to return to what was pointed out in the beginning of my discussion in connection with initial cost and maintenance of fuel "economizing" devices.

Study of air pre-heating in an ordinary furnace has shown, that construction of a rather small and of a very large recuperator costs more than fuel saved. The application of waste gases for fuel economies is limited from both ends, because the size of recuperator increases slowly in the first stages of waste heat recovery, grows then gradually to the middle of the curve and rises very fast when utilization is brought to a higher degree. At a certain point, the size of recuperator goes completely out of proportion with the economy achieved. Figures illustrating this study show, that recuperators, returning only 4% of waste heat, cost more than they save. From 5% to 25% of waste heat utilized is the profitable range of recovery, after which, it does not pay.

The same logic applies to the problem of waste gases' recirculation whether for thermal or chemical regime of heating furnace.

It is evident, that, in cases when it becomes profitable to use waste gases for their residual heat and fuel content, the combustion and heat transfer of the given heating aggregate are at fault. There can be visualized a furnace of such size and for such purpose, when a small fan can do the trick of recirculation of gases with some effect, but this exception will only confirm the general rule and show that over-all efficiency of such furnace is rather low even with the recirculation applied.

Recirculation can be also imagined as a temporary cure for abnormal conditions, when, for example, the roof or other arches of a furnace have to be protected from burning. Permanent remedy for such faulty conditions, however, lies in the correction of combustion and proper heat transfer and not in deliberate lowering of furnace efficiency.

Summing up the above, I wish to restate, that the design of a melting or heating furnace for metallurgical purposes, in normal conditions, should be based on the principles of proper combustion and heat transfer as can be developed by available fuel. The lowering of all-over efficiency of the furnace by dilution of gases and by recirculation of inert ballast hardly can be a paying proposition.

G. A. Merkt: This paper as presented was along the lines of that of Mr. Buell, who presented his paper this morning, i.e., a suggestion to give you an idea to work on. We already have certain ideas; we also know that our ideas have, to some extent, worked out very satisfactorily. All new ideas have to be tried gingerly in small doses. You can't get anybody to risk their equipment for a major installation of this kind. There is no question but that the information which has been collected, the thoughts which we have tried to put into a workable and practical system, are old;—nothing much is new about them. They must, however, be organized into something that is more usable and more controllable than the methods that have been used in the past. I am referring to recirculation; it has been utilized ever since furnaces were first used by simply plucking a hole through the flue and connecting this hole with the combustion end of the furnace with no means of regulation, no means of knowing how much came back. We are now incorporating recirculation

into an apparatus with which you can arrive at a definite relationship and keep it.

Coming back to this lengthening of the flame, or the rate of flame propagation, you can make a simple experiment very cheaply in your laboratory or shop by taking a four inch pipe, some twelve feet long, putting it in an upright position and using it as your furnace. Drill a hole in the center, i.e., half way up, to insert a small gas jet, also put a T-fitting at the bottom and a gas jet into it, at the bottom. One leg of the fitting stands on the ground and won't admit any air, the other serves as an air inlet. The latter you can open or close by a couple of boards. Then light the center burner. If you provide small window slots all the way up on that pipe and cover them with transparent mica, you can observe what is going on. After lighting this center or middle jet, you regulate the air through the bottom air gate until you get a fairly good combustion, comparatively short flame and of bright color. Now turn on the lower jet without disturbing the upper one. Turn on the lower jet rather full, and if necessary increase the air opening. Now the lower jet will consume a large portion of the air and will pollute the remainder of the air so that a mixture of air and products of combustion will finally reach the upper burner. Then it will be far more difficult for the gas of the upper gas jet to gain its supply of oxygen. Immediately its flame will shoot up four or five feet. You will also find that it will be more yellowish, and colder, i.e., it will not be as hot a flame as originally. That is very crudely what we might call "combustion conditioning."

Mr. Foss' extensive remarks, I am sure, are very interesting and instructive, particularly where the orthodox study of furnace construction and of heat production is concerned. Much sound advice is to be drawn from his discussion on such views as cost of construction, the futility of using recirculating waste gases in the process of making fuel gases and the relative value of waste heat recovery by means of recuperation. By far the largest part of Mr. Foss' discussion, however, seems to be a more or less complete disapproval of the various stages of consideration which I have offered in leading up to the proposed system of "Combustion Conditioning" and finally, the economy of any such scheme appears to be deemed negative. I appreciate such definite and frank opinion. As I will try to point out in a few instances, Mr. Foss is actually supporting the principal points of my views although invariably landing in an alien position.

Early in the discussion Mr. Foss complains that the Author's definition of the term "Thermal Equilibrium" is not completely correct and then ends his own definition with the statement that the heat transfer in every furnace is "In direct dependence of combustion conditions". This is, of course exactly what the development of the paper is based upon. Again later on, in comparing the relative effect in the combustion of blast furnace gas and of coke oven gas he admits the difference to lie in the difference of combustion condition of the fuels. These combustion conditions are, however, definitely influenced by the presence of inert or waste gases in the combustible mixture, as they are indeed also influenced by the patterns of combustibles in the mixture. Some very definite characteristics have been disclosed experimentally in connection with studies of the upper and lower limits of inflammability of various gas mixtures and much more technical data is hoped to be established along these lines by further research work.

In view of the apparent necessity for and practice of lowering the heat content of certain natural and industrial gases previous to distribution and sale to the consumer it is hardly correct to say that fuel technology is striving to produce gas fuels with concentrated heating value. The commercial gas industry is well aware of the undesirability for certain heating purposes of highly concentrated fuels, but is per force economically limited in its practice of softening heating values due to prohibitive cost of distribution per unit heat value. Quite naturally, in the production of fuel "per se" one would not go so far as to dilute it with inert or waste gases, but the reason for avoiding this is not by any means a lack of suitability, but the above mentioned cost of distribution and handling. Even so we must remind the reader of the widely adopted process and use of producer gas, one of the safest and most economical fuels for many purposes, containing considerable quantities of nitrogen and some carbon dioxide.

The reference to diffusion firing in the paper is not denying the phenomena disclosed by Mr. Foss but is calling attention to the difference in flame propagation in the combustion process by this method of bringing fuel and combustion air together and that resulting from turbulent combustion, which is more or less unavoidable in the ordinary furnace and port construction. The former is "delayed" as compared with the latter. Mr. Foss agrees that combustion conditions of gases diluted with products of combustion are "sluggish". Call it what you will, this sluggish combustion is akin to the performance termed delayed combustion as compared with the totally unrelated turbulent combustion of conventional furnace practice.

When speaking of over-all furnace efficiency Mr. Foss evidently has in mind the total production of heat (B.T.U.) and not the quotient of heat absorbed or used by the furnace charge divided by the total heat input. Unless all accepted laws and data of heat transfer are disputed, it is logically to be expected that the above mentioned quotient is increased if either convection or flame radiation or both are increased. This exactly is the purpose and aim of the combustion conditioning system described in the paper. The "Ballast" recirculated in the novel manner herein proposed does not add to the total heat (B.T.U.) produced by the fuel, in fact, although theoretically it neither subtracts any heat from the furnace system, there is a slight loss from the total due to the unescapable percentage loss of a greater volume, but the utilization of this same but "swollen" heat is vastly improved in excess of the above conceded loss for the reasons repeatedly given.

Coming back now to the opening remarks in the paper regarding the interest of management in furnace development, and the omission of the item of cost, it must not be assumed that this consideration has been neglected. On the contrary, the whole inception of the scheme as proposed is born of the idea to correct in the simplest and least expensive manner some of the inherent difficulties and deficiencies in the use of certain available fuels instead of attempting the much costlier problem of altering the fuel itself.

Heating Slabs For Hot Strip Mills

By W. R. CULBERTSON
Manager, Furnace Div., Rust Engineering Company, Pittsburgh, Pa.

▲ Presented before the Combustion Engineering Division of the A. I. & S. E. E. at the Twenty-ninth Convention in Pittsburgh, Pa., October 19, 1933.

W. R. CULBERTSON

The heating of slabs for wide strip mills presents a very exacting problem. Not only is it essential that the front and back edges, ends, and centers of the slab be uniformly heated, but the scale must also be of such a nature that it will clean up readily in the mill.

The original furnaces built for this work were similar to those which had previously been used on universal plate mills. They were of the end-charged, end-discharged type, with the slabs carried on water-cooled skids to within a short distance of the discharge knuckle. At this point there was a solid hearth long enough to accommodate two or three slabs. Just back of the solid hearth the furnace roof was usually restricted to drive the flame beneath the slabs. No burners were provided for firing underneath the steel. With this type of furnace it was found to be almost impossible to avoid "washing" the tops of the slabs, and it was very difficult to get the bottoms of the slabs hot enough for rolling.

The "washing" of the slabs caused considerable cinder and slag, which built up on the solid hearth in such proportions that each week during Sunday shut-down it was necessary to have a large force of men chip and clean the hearth. This was usually a very difficult job because at that time bottoms were made of various materials to which some of the slag would stick very tightly.

To get away from this high cost of hearth maintenance, the split-flame fired furnaces, which had been found to be very satisfactory for heating billets, were used for this purpose. In this type of furnace the steel was carried completely through the furnace on water-cooled skid pipes. An appreciable space was left below the skid pipes for the travel of gases, and the ports were so designed that as the flame expanded, it filled the entire furnace from top to bottom. The solid hearth having been eliminated, a coke breeze bottom was used in the space below the skids at the discharge end, so that cinder could easily be cleaned out through doors provided in the side walls. This greatly cut down maintenance costs. However, this type of furnace also proved unsatisfactory on slabs more than twenty inches wide, for it was found to be impossible to avoid heating the front edge of the slab hotter than the back edge, which caused the slabs to buckle in the mill. The cold spots left by the water-cooled skids were also found to be detrimental. A great deal of cinder was caused by melting the front edges of the slabs.

The next type of furnace used had water-cooled skids extending through the furnace to a point near the discharge knuckle, from which point a solid hearth of appreciable length was installed practically the same as the original furnace, except that underfiring was provided. The major part of the fuel was still fired from the discharge end of the furnace above the slabs, and the remainder of the fuel was applied beneath the steel through burners located directly back of the soaking hearth. This type of furnace was found to be very satisfactory at one particular tonnage, that is, the tonnage for which it was designed. However, if an attempt was made to drive the furnace beyond this tonnage, it resulted in overheating of the slabs on the hearth with resultant cinder trouble and the same hearth difficulties as originally experienced. When operating at low tonnages it was necessary to carry a highly reducing atmosphere in order to reduce the flame temperature to avoid overheating on the hearth. In most continuous strip mills there are numerous mill delays due to cobbles, size changes, etc., and it was impossible with this type of furnace to maintain a uniform temperature in the slabs being discharged to the mill. Also because of the large amount of fuel necessary to hold the large combustion chamber at rolling temperature, the steel toward the charging end of the furnace heated up rapidly during delays, resulting in excessive scale. Fig. 1 illustrates the various furnaces mentioned above and the process of development.

To overcome these troubles, a type of furnace which had previously proved itself in the heating of blooms, billets, and other sections was offered to the steel trade. This furnace has come to be known as the zone-controlled, triple-fired type. Fig. 2 shows a section of this furnace. As you will note, this type of furnace, which is end-charged, end-discharged, consists of a primary heating chamber with burners located both above and below the steel. The steel slabs are carried on water-cooled skids through this part of the furnace. On leaving this primary

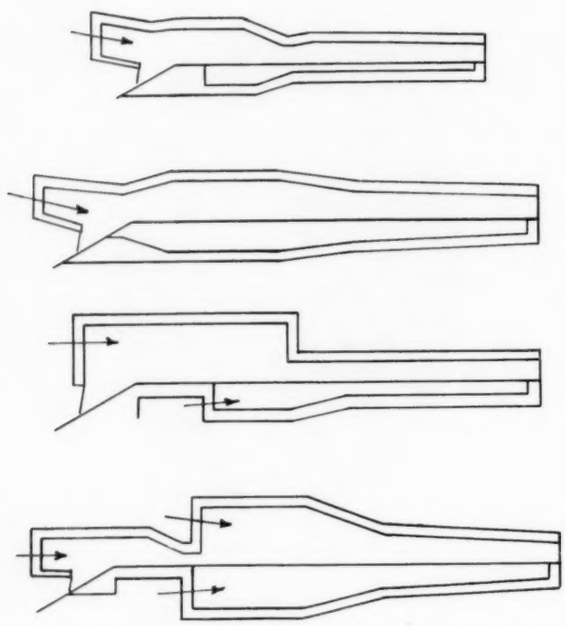


FIG. 1

heating chamber, the steel, which is approximately up to rolling temperature, is pushed into a soaking chamber separated from the heating chamber by a low-hanging roof, which is independently fired with burners of sufficient capacity to overcome radiation losses and provide the small additional amount of heat required by the slabs. A solid hearth, usually built of plastic chrome material, is used in this chamber, and the hearth is of sufficient length to provide a soaking time of twenty to thirty minutes. As the slabs progress through this chamber they are soaked uniformly to rolling temperature without "washing" and are discharged from the end of the furnace through a mechanically-operated door which can either be operated manually or electrically interlocked with the pusher. The function of this door is to eliminate as far as possible air infiltration to the soaking chamber, and all of the recent installations of this type of furnace on slab mills have proved very effective. It was found that these furnaces not only greatly improved the heating, but also improved the nature of the scale on the slabs. This can be accounted for to some extent by the fact that in the main heating chamber where the steel is cold, a high flame temperature may be used, which results in a very high rate of heating without the danger of "washing" the slabs. In this manner the heating time is reduced; also, there is a continuous rise in temperature from the time the steel is charged until it is discharged, both of which factors contribute to producing a thin scale which cleans up readily. While the furnaces which had previously been built were suitable for only one particular tonnage, this type of furnace can be operated economically at from 25% to 125% of rating. In all cases, the amount of fuel fired in the soaking chamber and the temperature in this chamber remain practically constant, and the amount of fuel burned in the main heating chamber is varied in accordance with the tonnage produced. This soaking chamber lends itself readily to the use of automatic temperature control equipment, and thus the slabs in this chamber can be discharged at any predetermined temperature necessary for rolling. This absolutely insures against "washing" and overheating with the resultant cinder and hearth troubles.

In the old type of furnace it was necessary to reduce the flame temperature when operating at low tonnages. This could only be accomplished by running a high excess of fuel which resulted in a long flame, heating the steel excessively at the charging end of the furnace and causing a large amount of scale. As had been expected, the triple-fired furnaces were extremely economical since the amount

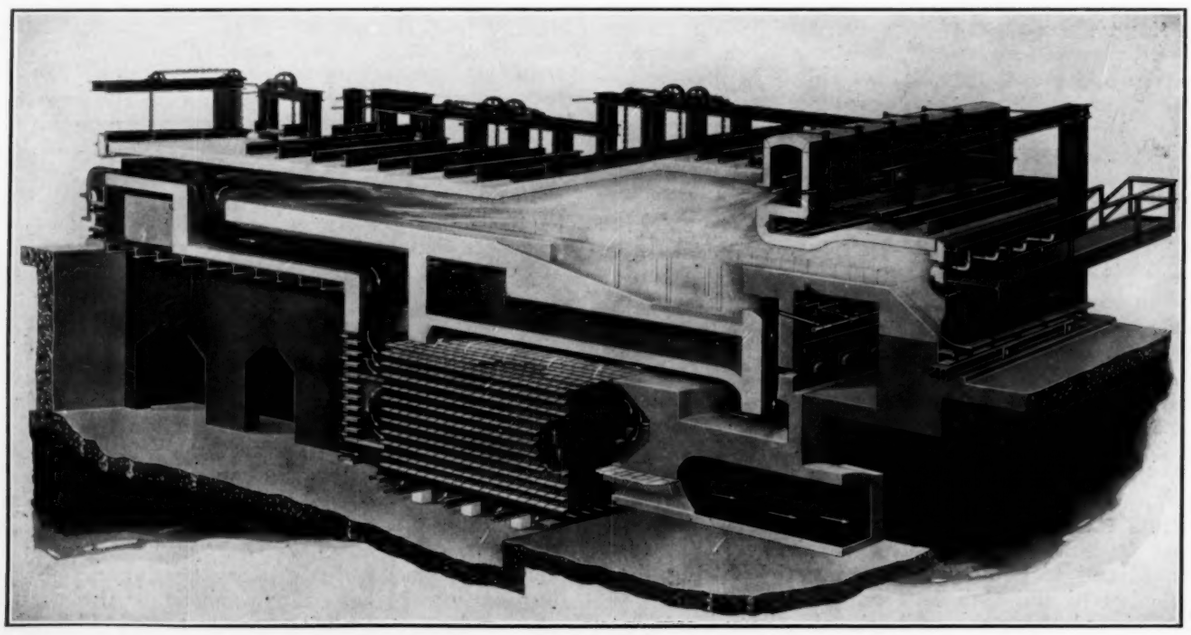


FIG. 2

of fuel burned in the main heating chamber can be varied directly in proportion to the tonnage produced. Another reason for economy lies in the fact that when heating up the furnaces after a shut-down, the soaking chamber is heated up first and it is not necessary to light the burners in the main heating chamber until a short time before the mill is ready to roll. It is also possible to obtain much higher capacity from furnaces of identical size by the use of zone firing, for in the heating chamber, where the steel is cold, high temperatures can be maintained without fear of overheating the steel. This makes possible a higher average furnace temperature which, in turn, produces higher tonnage. Maintenance has also been greatly reduced, for although a high flame temperature is maintained in the main heating chamber, the cold steel absorbs heat rapidly enough to prevent overheating of the refractories.

Preheated air is always recommended for the main heating chamber and only for the soaking chamber when low B.T.U. fuels are used, such as producer gas, etc.

The zone-fired furnace is not only being used in the new mills producing strip steel from wide slabs, but also successfully in tube, universal plate, merchant, structural, bar, rod, and rail mills.

Discussion

Discussion Presented by

J. L. Miller, Asst. Chief Engineer, Carnegie Steel Company, Youngstown, Ohio.

F. E. Leahy, Fuel Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

W. R. Culbertson, Manager Furnace Division, Rust Engineering Co., Pittsburgh, Pa.

H. V. Flagg, Asst. Combustion Engineer, The American Rolling Mill Co., Middletown, Ohio.

H. Dobrin, Consulting Fuel Engineer, Pittsburgh, Pa.

M. J. Conway, Fuel Engineer, Lukens Steel Company, Coatesville, Pa.

G. T. Hollett, Steam Engineer, Illinois Steel Co., South Chicago, Ill.

J. L. Miller: I think Mr. Culbertson's paper has been very interesting and I feel that he has brought out the development of the modern slab heating furnace in a very clear manner. I believe we all appreciate the difficulties which we get into from an extremely low heating rate on the hearth of any re-heating furnace as well as those entailed on the very high or overheating demands on the same furnaces. These are matters which we in the field must cope with to the best of our ability on existing installations.

F. E. Leahy: I would like to ask a question. In the remarks it was stated that the furnace would operate from 25 to 150 percent. I would like to know the basis of the rating, pounds per square foot, or whatever basis you would use?

W. R. Culbertson: These furnaces usually are calculated to heat around a 100 to 120 pounds per square foot. We have operated as low as five pounds per square foot during the times when the demand is not great, but ordinarily they all run at the regular rate of capacity.

J. L. Miller: I think the rating for "capacity" on a billet heating furnace might become very difficult of agreement without any local limitations agreed upon.

H. V. Flagg: Mr. Culbertson's paper has been very interesting. Of all steel mill heating problems, that of heating slabs is perhaps most exacting. The size of furnaces required, the large door openings to be kept under control, the considerable amount of fuel required, and the necessity for even distribution of heat over a large surface so that a thick section can be heated to high temperature uniformly from edge to middle, from end to end, and from side to side, in a relatively short space of time, with easily handled surface scale, all conspire to make the construction of a completely successful slab heating furnace exceedingly difficult.

J. L. Miller: The intimations here made of poor bottom heating are extremely interesting. Our wish for a good slab heating furnace seems to be merely the father of a thought. Some form of split flame firing is surely equal to doing such heating effectively and efficiently.

A Member: I would like to ask Mr. Culbertson approximately how many pounds of coal is used to operate this furnace on slab heating?

W. R. Culbertson: Actual fuel consumption on cold steel runs approximately 160 to 170 pounds of coal to a gross ton;—on hot steel, 100 to 120.

J. L. Miller: That is in operation now?

W. R. Culbertson: Yes.

H. Dobrin: Mr. Culbertson's paper was very interesting; the only thing about it is that he has covered only one brief phase of the problems that have concerned most of us, namely, the proper application of heat in the field of metallurgical heating. Mr. Flagg is partly correct that it has been very difficult to find the ideal method for heating slabs, especially would this be the case with the kind of slabs that Mr. Flagg has to deal with. These slabs are almost ingots. At the same time it must be admitted that some very substantial progress has been made along this line and that there are some very good slab furnaces now in service.

Mr. Merkt has also presented us with a very interesting paper. True, he has tried to cover so many different subjects in such a brief paper as to make it impossible to do justice to either one of these subjects. The question of diffusion flame, luminosity, design of furnace lines, all call for some very comprehensive treatment as they have agitated the minds of many of us who have been wrestling with these problems from their inception. Out of all these good papers there always results some good, and the art of proper heat application is being advanced slowly but surely.

The Society is fortunate to have men who devote their time and thought to the advancement of this very intricate and fine art.

M. J. Conway: Mr. Culbertson has given us a very good case history in the development of zone fired continuous furnaces; this coupled with combustion and temperature control is a far cry from the old pusher type discharge end fired furnace, and should prove worthy of consideration in displacing in and out slab heating furnaces at some mills, with a consequent saving of labor and fuel.

G. T. Hollett: It is very important to have the

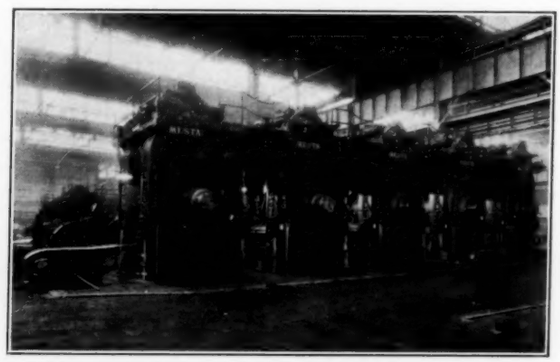
triple fired furnaces equipped with individual control for air and gas for every burner. The individual control on each burner allows the operator to regulate the rate of air and fuel to each burner and to secure a correct distribution across the width of the furnace. Each group of burners such as the upper heating zone, lower heating zone, and soaking zone should have a separate gas and air control valve to allow the operator to regulate the rate of heating for the various zones of the furnace.

Draft control is very essential to this type of furnace as well as for the older types of furnaces. Since the volumes of gas can be regulated to conform to the rate of steel required by the mill operation, it is very essential that the draft be regulated so as to carry a balanced condition within the furnace regardless of the volume of waste gas leaving the furnace.

It is a difficult problem to keep the front edge of the steel next to the discharge end of the furnace at the proper temperature. If the flame impinges on the steel there will be a washing effect and if the flame is too far above the steel there will be excessive air coming in contact with the steel which will cause scaling and unequal heating. Several methods have been employed to overcome this difficulty. Auxiliary burners may be installed that are directed towards the discharge slope below the steel. Excess oxygen that enters around the discharge door may be consumed and the front edge of the steel kept at the proper temperature. Also, the burner for the soaking zone may be located near the top heating zone and directed towards the discharge end of the furnace. The products of combustion travel in the same direction as the steel until striking the wall of the furnace where the products of combustion are deflected downward towards the steel and then drawn backward over the slabs towards the charging end of the furnace. This arrangement has its advantages since the products of combustion, after striking the discharge end of the furnace, are deflected downward where they back up any free oxygen and prevent the slabs from excessive action of the free oxygen. Also, by this method the fuel is burned away from the slabs and only the neutral products of combustion need come in contact with the heated steel. This arrangement has its disadvantages since a large part of the furnace below the upper burner is practically ineffective and a longer furnace is required for equal heating capacity.

It seems to me that this type of furnace, i. e. the zone fired furnace is the most effective way of maintaining properly heated steel for the modern continuous mill, particularly as the weight of steel through the furnace must be varied to suit mill conditions.

New Inland Tin Plate Plant Now in Operation*



New Inland tandem cold rolling mill for the production of Inland Tin Plate from hot rolled strip. This mill will reduce 16 gage steel strip to 38 gage black plate 36" wide. It is equipped with gaging devices to insure accuracy of gage.

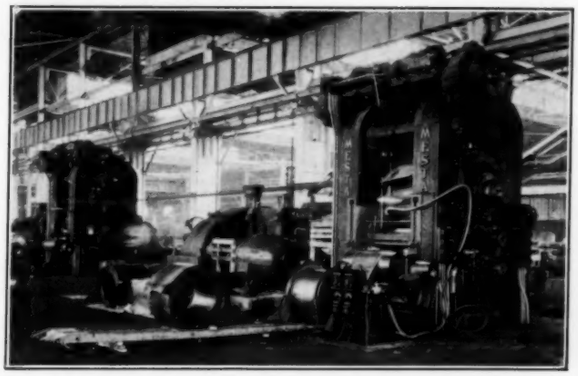
In 1931 the Inland Steel Company built a large continuous strip mill at its Indiana Harbor, Indiana, Works for the production of flat and coiled strip and plates. This mill is capable of rolling plates up to 72" wide. At the same time a cold rolling department was built, complete with the necessary continuous pickling equipment. In this cold rolling department the hot rolled strip is reduced to desired gage by a series of cold mills in tandem, after which the material is cut to sheet lengths, annealed and finished. This mill produces cold rolled sheets principally for the automobile industry.

The Company has now completed the third step in the original program, and has installed equipment for the manufacture of tin plate, the black plate being produced from the hot rolled strip by cold reduction. For this purpose, two mills have been installed. The first consists of a train of five exceptionally heavy mills through which the material passes successively, and is reduced to desired gage. This mill will be capable of rolling material 36" wide to 38 gage, or 55 lb. tin plate.

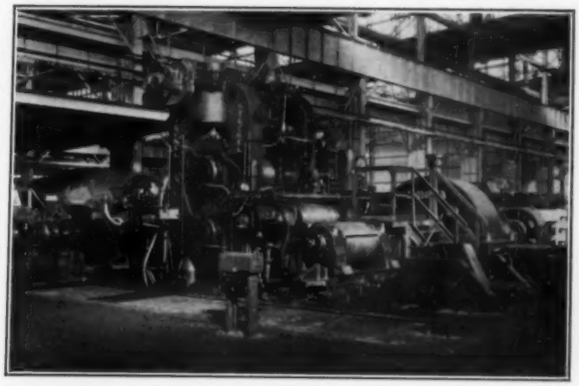
This mill has been built exceptionally heavy, and provided with ample power to make the necessary reductions in this wide material, and is equipped with gaging devices to insure accuracy of gage of the finished material. The mill is designed so that the maximum delivery speed may be as high as 700 feet per minute.

In addition to this train, the Company has also installed a 38" Steckel mill principally for the purpose of producing light weight material. In this type of mill, as is well known, the hot rolled band is pulled back and forth between the rolls a number

* For additional information on the Inland Steel Company's Indiana Harbor Works refer to Stephen Badlam's paper "Recent Developments in the Rolling of Sheet and Strip" published in the December, 1933 issue of the Iron and Steel Engineer.



One of the heavy, 4-High type skin rolling mills in the new Inland Tin Plate plant. Here, annealed steel strip is finished and after trimming and shearing it is in the form called black plate.



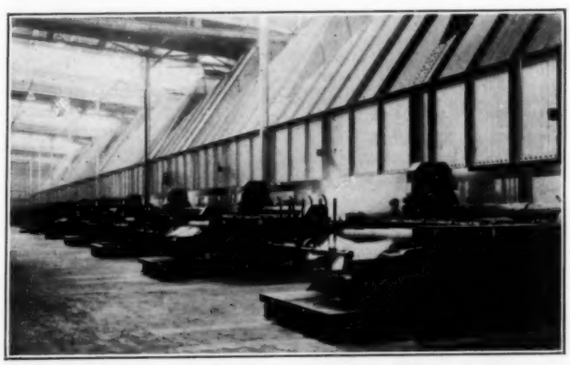
Steckel mill in the Inland Steel plant for rolling light gage steel strip which may be used for tin plate.

of times until the desired reduction has been obtained. The working rolls are not driven, power being supplied by the reels on either side of the mill applying tension to the material. This mill has many novel features compared with previous installations of this type of equipment. It is anticipated that the capacity of these two units will enable the Company to produce 10,000 tons of cold rolled black plate per month.

After the hot rolled bands have been reduced to the desired gage in the cold rolling department, they are transferred to a separate building where further processing is carried out. The first step is to thoroughly free the cold rolled bands of all traces of oil. This is accomplished in an electrolytic cleaning device, which is particularly effective for this purpose. After the coils have been thoroughly cleaned and dried they will be annealed in a series of furnaces. The coils are generally mounted two high on the annealing bottoms and covered by a circular alloy cover, properly sealed to prevent air from having access to the coils during the annealing period. After the coils are annealed, they are transferred to a coil cooling building where they will be allowed to cool until reaching room temperature. As the coils are required for further processing they will be transferred to the skin rolling mills by tractors.

These skin rolling mills are of the heavy 4-high type, and are designed to allow any degree of cold rolling that may be required to give the necessary temper to the black plate. From these cold rolling mills the material passes into the trimming and flying shears where it is trimmed to width and cut to length at a rate of approximately 300 feet per minute. The cold rolled bands are now in the form of black plate of the size required to fulfill customer's order. In this form the individual sheets will be inspected and sorted to eliminate any off weights or defective material. They will then be ready for the tinning operation, which will be similar to the process used in other tin mills. They will be given a white pickel immediately prior to tinning, and stored in boshes, from which they will be transferred to the tinning machines. The other operations in the production of tin plate are the same as practiced in other plants.

The Inland Steel Company's decision to install this plant was part of the original plan of development to absorb the products of the strip mill installed in 1931. The superior surface, evenness of gage and other properties of tin plate production by the cold reduction method has been well demonstrated, and the Inland Steel Company has therefore installed what represents the largest and the most complete installation for the purpose of producing this class of material.



Tinning department—new Inland Tin Plate plant—showing delivery end of tinpots.

ASSOCIATION NOTES

COMING MEETINGS AND PAPERS

CHICAGO SECTION

Electric Association, 20 N. Wacker Drive
K. E. Dinius, Chairman A. J. Whitcomb, Secretary
Dinner 6:30 P. M. Meeting 7:45 P. M.

Wednesday, February 28, 1934

"CLEANING OF BLAST FURNACE GAS."

1. Operation of Electric Precipitator Installation at South Works, by G. T. Hollett, Steam Engineer, South Works, Illinois Steel Co.

2. Electrical Features of Electric Precipitator Installation at South Works, by K. E. Dinius, Chief Testing Engineer, Illinois Steel Co.

3. Discussion, by H. M. Pier, Research Corporation, Chicago, Ill.

4. Discussion, by S. F. X. Plaisance, Engineering Department, General Electric Co., and others.

5. Other discussions of electric precipitators which are used for cleaning blast furnace gas, will cover in particular a comparison in mechanical and tube rectifiers.

* * * *

PHILADELPHIA SECTION

Engineers' Club, 1317 Spruce St.

W. H. Burr, Chairman L. O. Morrow, Secretary

Dinner 6:00 P. M. Meeting 7:00 P. M.

Saturday, March 3, 1934

"Insulation and Insulation Lacquers for Cables and Coils," by C. F. Hanson, Elec. Eng., Irvington Varnish & Insulator Co., Irvington, N. J., and E. W. Davis, Elec. Eng., Simplex Wire & Cable Co., Boston, Mass.

Saturday, April 7, 1934

"General Ideas and Discussion." Every active member is invited to prepare a short paper on a subject pertaining to the application of Electricity to the Iron and Steel Industry.

Some of the papers to be presented are as follows:

"Reactors Vs. Resistors in Industrial Control," by F. O. Schnure, Supt., Elec. Dept., Bethlehem Steel Co., Sparrows Point, Md.

"Variable Speed Motors for Accumulator Pumps," by R. F. Gale, Plant Eng., Midvale Co., Philadelphia, Pa.

ITEMS OF INTEREST

H. J. Freyn, president of the Freyn Engineering Co., Chicago, since it was founded, has been elected chairman of the board and has been succeeded to the presidency by Wyman Eaton, recently vice president. Mr. Freyn is an associate member of the A. I. & S. E. E. Gordon Fox, formerly power engineer, and Alfred J. Ebner, formerly mechanical engineer, have been made vice presidents. L. T. Shorley has been re-elected secretary and treasurer.

GORDON FOX

Mr. Eaton became associated with the Freyn company in 1919 as chief engineer, later becoming vice president and general manager.

Gordon Fox, an associate member of the Association of Iron and Steel Electrical Engineers, entered the Freyn organization in 1920 and has been identified with its power and electrical activities. He has spent the last five years largely in the USSR, where the Freyn company, in association with the Russian organization, Gipromez, has co-operated in the development of the steel industry there. From 1914 to 1920 Mr. Fox was electrical engineer of the Steel & Tube Co. of America and its predecessor, the Mark Manufacturing Co., Chicago.

Mr. Fox has presented many valuable papers and discussions before the A. I. & S. E. E. Very recently he presented a Russian travelogue before the Pittsburgh sections of the A. I. & S. E. E., A. I. E. E. and Engineers Society of Western Pennsylvania. One of the largest crowds ever to attend any Engineering meeting in this district greeted Mr. Fox on this occasion.

Mr. Fox will also be remembered as the author of the well known book "Electric Drive Practice."

Alfred J. Ebner has been with the Freyn company since 1916, specializing in blast furnace and open-hearth work.

▲

The Perin Engineering Company of New York, under whose supervision Sheet Mills in India were modernized, announce receipt of cable on February 15 to the effect that, in 16 shifts of the week ending February 10, 1934, on one of the modernized mills, there was made 792 gross tons of sheared sheets, 94.6% of which was 24 gauge. The maximum shift was 63.45 tons.

▲

Forrest U. Webster, for seven years advertising manager of Cutler-Hammer Inc., Milwaukee, has been named manager of merchandising sales and will continue to supervise advertising. He has been succeeded as advertising manager by L. P. Niessen.

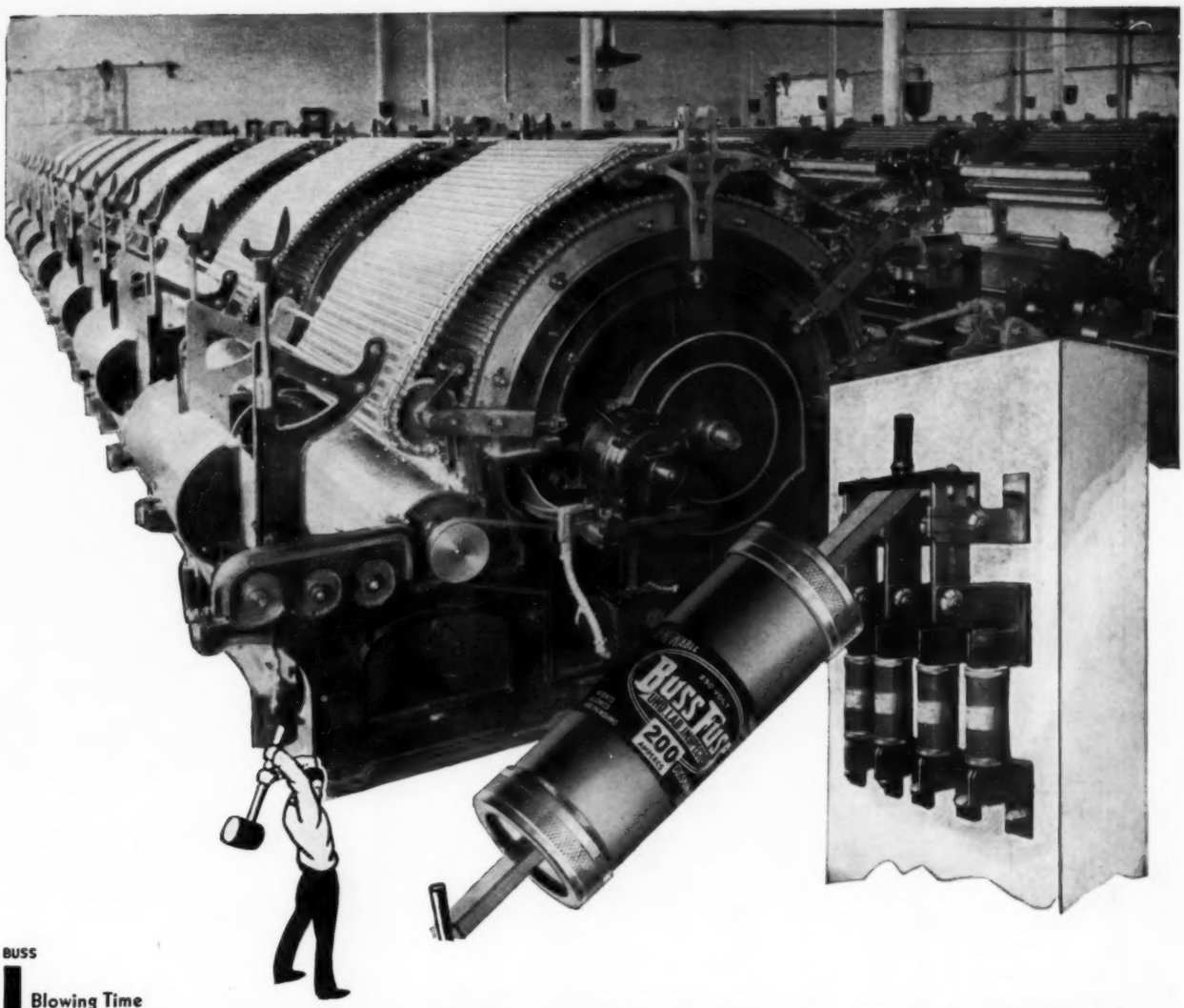
▲

OBITUARY

Mr. E. H. Wentz, an active member of the A. I. & S. E. E. for twenty-three years, died at his home, 221 Columbus avenue, Elyria, Ohio, on Monday, February 5, 1934. Mr. Wentz at the time of his death was Superintendent of Shops at the Lorain (Ohio) plant of the National Tube Company. Mr. Wentz took an active interest in the Association and during the course of his membership he served as a Director and on many National Committees. His opinions, ideas and experiences as reflected in his discussions of papers presented are very valuable additions to our Proceedings.

E. H. WENTZ

The membership of the A. I. & S. E. E. extend their sympathies to the friends, associates and family of this electrical pioneer in the Iron and Steel Industry.



BUSS

Blowing Time of BUSS SUPER-LAG Fuse Compared to Other Makes.

This chart shows results obtained in tests made by Electrical Testing Laboratories of New York as reported by them August 25th, 1930 on the 200 ampere 250 volt size. 30, 60, 100, 400 and 600 ampere sizes as reported by them show similar results.

HOLD THAT LINE!

BLOCK NEEDLESS DELAYS—

Sounds like football, but doesn't it apply to fuses too? Surely you don't want fuses to break down and throw your lines out of service every time there is a little extra surge of current.

Wouldn't you rather have fuses that will hold the lines in operation, keep machines running and the lights on? Fuses that will hold most of these harmless overloads yet will blow promptly *on short circuits or dangerous overloads*?

Just glance at the chart to the left. It gives you an idea of how the new BUSS SUPER-LAG Fuse compares with old type fuses. Now you can fortify your plant against those annoying current surges that have heretofore been so difficult to control.

Why not specify BUSS SUPER-LAG Fuses on your next order? Or let us send our nearest representative to consult with you on your fuseing problem.

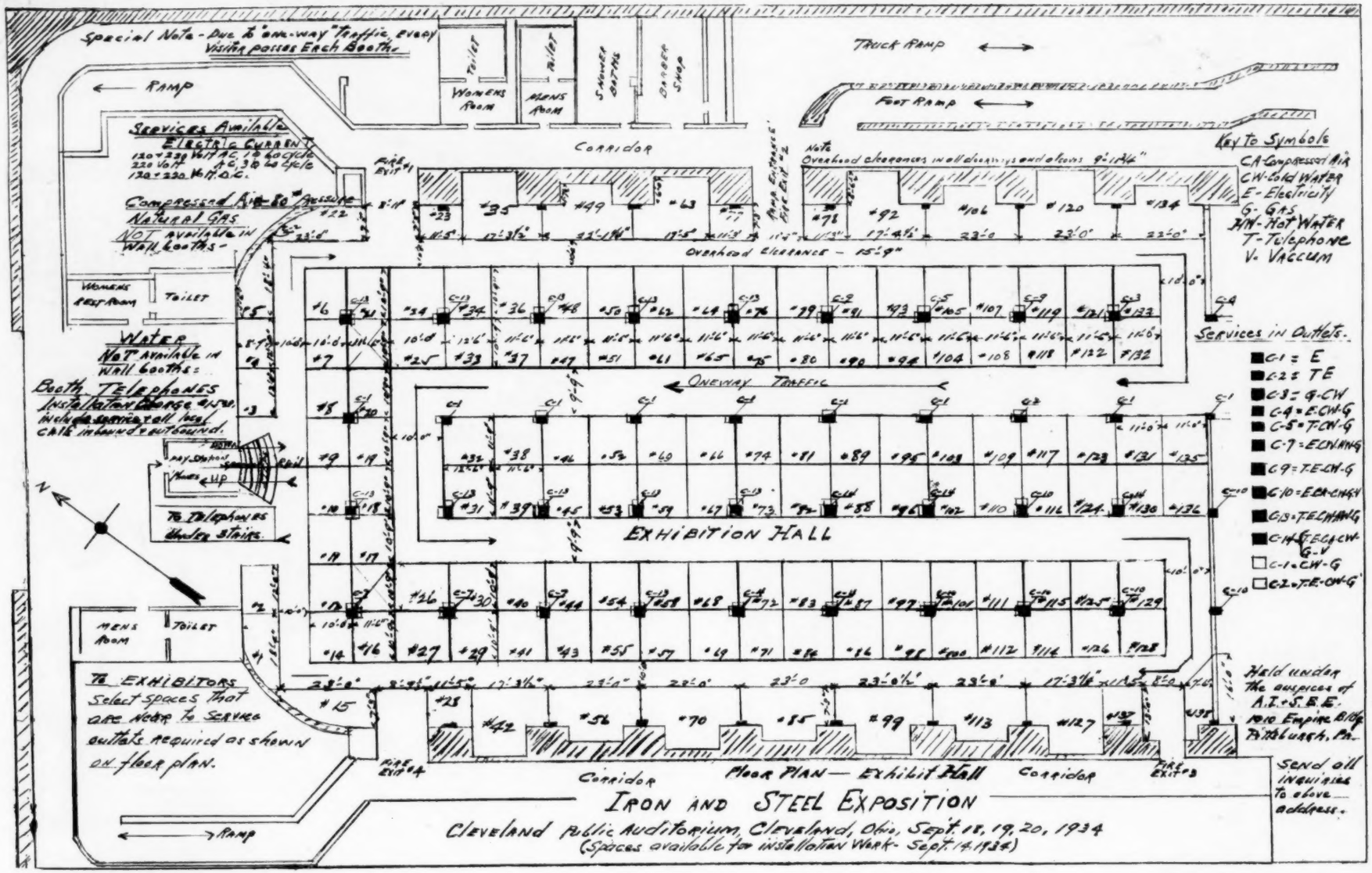
If you prefer more information before taking definite action, drop us a line and we will send you complete information by mail about the new BUSS SUPER-LAG Renewable Fuse.

BUSSMANN MFG. CO., ST. LOUIS, MO.
A Division of the McGraw Electric Company

BUSS SUPER-LAG FUSE

IRON AND STEEL EXPOSITION

CLEVELAND, OHIO, SEPTEMBER 18, 19, 20, 1934



Floor plan of the Iron and Steel Exposition to be held under the auspices of the Electrical, Mechanical, Lubrication, Combustion and Safety Engineering Divisions of the Association of Iron and Steel Electrical Engineers, Cleveland, Ohio, September 18, 19, 20, 1934. An exposition of the developments in apparatus and equipment to process and produce Iron and Steel.